Published Monthly. Price, $5.00 per Annum.

THE JOURNAL

OF THE

AMERICAN CHEMICAL SOCIETY,

AND

JOURNAL OF ANALYTICAL AND APPLIED CHEMISTRY.

VOL. XV.—NO. 8.

AUGUST, 1893.

[Issued November 10, 1893.]

COMMITTEE ON PAPERS AND PUBLICATIONS:
EDWARD HART, Editor, J. H. LONG, EDGAR F. SMITH.

CONTENTS.

	PAGE.
On Chemical Energy. By Dr. W. Ostwald	421
The Fundaments of Chemical Theory. By J. E. Trevor	430
Work of the Committees on the "International Standards for the Analysis of Iron and Steel." By John W. Langley	448
Standardizing the Torsion Viscosimeter. By O. S. Doolittle	454
Progress in the Manufacture and Use of Artificial Coloring Matters. By Otto N. Witt	456
How Chemistry is Best Taught. By Charles F. Mabery	463
Patents of Interest to Chemists. Edited by Albert H. Welles	475
New Books	478
Note	480
Erratum	480

EASTON, PA.:
CHEMICAL PUBLISHING COMPANY.

Entered at the Post Office, Easton, Pa., as Second Class Matter.

OFFICERS OF THE AMERICAN CHEMICAL SOCIETY.

President: H. W. Wiley, Dept. of Agriculture, Washington, D. C.

Vice Presidents: J. H. Appleton, Brown Univ., Providence, R. I.
C. R. Stuntz, Woodward High School, Cinn., O.
P. T. Austen, Brooklyn Poly. Inst., Brooklyn, N. Y.
F. P. Dewey, 621 F st., Washington, D. C.

General Secretary: Albert C. Hale, 551 Putnam ave., Brooklyn, N. Y.

Treasurer: C. F. McKenna, 424-426 E. 23d st., N. Y. City.

Librarian: F. E. Dodge, 248 Eleventh st., Brooklyn, N. Y.

Committee on Papers and Publications: Edward Hart, Editor, Lafayette College, Easton, Pa.; E. F. Smith, Univ. of Penna., Phila., Pa.; J. H. Long, 2421 Dearborn st., Chicago, Ill.

Committee on Nominations to Membership: C. A. Doremus, 103 E. 16th st., N. Y. City; A. A. Breneman, 97 Water st., N. Y.; William McMurtrie, N. Y. Tartar Co., 106 Wall st., N. Y. City.

Finance Committee: A. P. Hallock, 440 First ave., N. Y. City; Durand Woodman, 80 Beaver st., N. Y. City; Frank T. King, 91 Columbia Heights, Brooklyn, N. Y.

Board of Directors. Members ex-officio: H. W. Wiley, Pres., Albert C. Hale, Gen. Sec., C. F. McKenna, Treas., F. E. Dodge, Librarian, Edward Hart, Editor. *Term expires Dec. 1893:* C. A. Doremus, 103 E. 16th st., N. Y. City; Peter T. Austen, New Brunswick, N. J.; Durand Woodman, 80 Beaver st., N. Y. City; C. F. Chandler, School of Mines, Columbia College, N. Y. City. *Term expires Dec. 1894:* A. H. Sabin, Box 85, Long Island City, N. Y.; A. A. Breneman, 97 Water st., N. Y. City; A. R. Leeds, Stevens Institute, Hoboken, N. J.; W. McMurtrie.

Council. Members ex-officio: H. W. Wiley, Pres., Albert C. Hale, Gen. Sec., Edward Hart, Editor. *Term expires Dec. 1893:* J. H. Appleton, Brown University, Providence, R. I.; C. E. Munroe, Columbian University, Washington, D. C.; C. F. Chandler, School of Mines, Columbia College, N. Y.; T. G. Wormley, University of Pennsylvania, Phila., Pa.; C. B. Dudley, Altoona, Pa. *Term expires Dec. 1894:* G. F. Barker, 3909 Locust st., Phila., Pa.; Alfred Springer, 46-50 E. 2d st., Cincinnati, O.; F. W. Clarke, Chief Chemist U. S. Geol. Surv., Washington, D. C. *Term expires Dec. 1895:* G. C. Caldwell, Ithaca, N. Y.; J. W. Mallet, Univ. of Virginia, Charlotteville, Va.; T. H. Norton, Cincinnati Univ., Cincinnati, O.; A. B. Prescott, Univ. of Mich., Ann Arbor, Mich.

Local Sections. Rhode Island Section: J. H. Appleton, Pres. Officer, E. E. Calder, Sec., Board of Trade Building, Providence, R. I. *Cincinnati Section:* Chauncey R. Stuntz, Pres. Officer, W. Simonson, Sec., 9th and Race sts., Cincinnati, O. *New York Section:* P. T. Austen, Pres. Officer, Morris Loeb, Sec., 37 E. 38th st., N. Y. City. *Washington Section:* F. P. Dewey. Pres. Officer, A. C. Peale, Sec., cor. 12th and F sts.

Members wishing extra copies of the Journal may obtain them of F. E. Dodge, Librarian, 248 Eleventh street, Brooklyn, N. Y., at the rate of $3.00 per annum.

VOL. XV. AUGUST, 1893. NO. 8.

Issued November, 1893.

THE JOURNAL

OF THE

AMERICAN CHEMICAL SOCIETY.

ON CHEMICAL ENERGY.[1]

BY DR. W. OSTWALD, OF THE UNIVERSITY OF LEIPZIG.

DURING the scientific development of chemistry, the hypotheses which have served as a primary foundation have always been borrowed from a prominent sister science. At the time of the most rapid development of mechanics as founded by Galileo and advanced by his pupils and successors, chemistry was mechanical; the solvent action of acids upon metals was explained by assuming that the former posessed points and edges by means of which they disintegrated the latter; bodies which combine were supposed to have hooks by means of which they attatched themselves to each other. When Newton based his theory of astronomical movements upon the assumption of a force acting inversely as the square of the distance, chemistry shortly appropriated this idea, and traced all processes to the attraction and repulsion of particles. It is, therefore, not surprising that the phenomena of the Voltaic pile (which later proved to be so intimately connected with chemical changes) were at once utilized to serve as a foundation for a theory of chemical processes. These theories, especially that of Berzelius, have prevailed a long time, but finally have proved themselves just as insufficient to represent chemical phenomena as the mechanical and the attraction theory.

Thus the theory of chemical combinations is to-day a strange

[1]Read before the World's Congress of Chemists Aug. 26, 1893.

10-26-93

and contradictory conglomerate of the fossil constituents of the earlier theories. The rudiments of the theory of attractions still play the most important role, while there is also considerable discussion about positive and negative elements, *i. e.*, the residues of the electro-chemical theory, and in most recent times we see the long-forgotten mechanical conceptions again stepping to the front in stereo-chemistry and being accepted by many as a new step in the progress of science.

In such times it is of great value on the one hand to recall the historical development and the evanescence of theories; on the other hand to find in the older theories that which is useful and correct, so as to obtain sound building material for a new theory.

Especially are we forced to conclude from the fate of past theories, that chemical phenomena must be explained by their own interrelations, that is, must be logically arranged. The use of analogies from other fields of natural science has indeed often led to suppositions which for the moment seemed satisfactory; on trial, however, such analogies have always proved themselves more a drawback than a help, since they hindered the unbiased comprehension of facts, and they could not (or will not in the future) be cast aside without a great struggle and considerable sacrifice of time and labor.

It is scarcely needful, at present, to prove that the several provinces of quantitative science possess in a single conception both the principle which distinguishes them and that common principle which unites them, namely, the conception of energy. Mechanical energy is distinct from thermal; similarly, chemical energy is distinct from electrical; and in each province progress can only be made by studying the various properties which the form of energy under examination possesses.

At the same time, however, the laws which determine the correlation and conservation of energy constitute the only bond which unites the various fields. If heat could not be changed into mechanical energy, and chemical into electrical, these provinces would stand distinct and isolated from each other; and neither thermodynamics nor electro-chemistry would be possible. This shows that progess in the scientific conception of chemical phenomena depends upon primarily determining the

several properties of chemical energy as such, and then its relation to other forms of energy; this done, we will be able to cope in a scientific manner with each chemical process, no matter whether it leads to other chemical changes or causes the appearance or destruction of other forms of energy.

The knowledge of the laws of chemical energy is not only scientifically but also practically of the greatest interest. All energy which is employed in accomplishing the various purposes of industry is derived from chemical sources, the combustion of fuel. Besides each step that we take, every word that we speak, in fact every thought formulated by our brain, leads to sources of chemical energy; animals and plants throughout their whole existence are based primarily upon chemical energy and its laws, and the ultimate problems of biology are in every respect chemical.

All forms of energy have this in common, that they may be resolved into two factors, both of which have definite properties. The one, which we call intensity, determines whether the energy may remain at rest, or must undergo an exchange. Thus, for instance, the factor of intensity for heat is temperature, since we know that two bodies can be at rest with reference to their heat only when their temperatures are equal. The second factor we call capacity; it determines how much energy at a given intensity is present in the object under consideration. With heat, for instance, this is called heat capacity.

What now are the factors of chemical energy? If we had a measure for its factor of intensity, as the thermometer is a measure of the intensity of heat, we would be able to determine for each substance with reference to another whether it could react with the latter or not, just as the thermometer shows us whether or no heat can be transmitted from one body to another. Our answer is that this question has not been completely solved, but that for many phenomena we already possess a chemometer, as we might call the instrument—in analogy to the thermometer.

In order, however, to be able to explain the theory of the chemometer, the factors of chemical energy must first be more precisely determined. The factor of capacity is in this case most easily discovered. The chemical energy which is present under given circumstances is proportional to the weight or mass

of the substances involved. Hence we sell and buy chemical energy according to weight. This becomes more clear from the following consideration: When we buy coal, we do not consider the carbon present, but rather the chemical energy, since in the use of the fuel we allow the carbon to escape quietly through the chimney as carbon dioxide, without making any effort to retain it; that, however, which we husband with the greatest care, is the chemical energy of the coal, obtained as heat. I have stated with due consideration that the factor of capacity of chemical energy is proportional to the mass; yet it is not mass, since this conception belongs solely to mechanics. It is therefore by no means more correct to say "atomic mass" instead of "atomic weight," since in this case the degree of chemical capacity is concerned which is proportional to both weight and mass, without being one or the other.

The term "degree of intensity" of chemical energy has something in common with the conception which has become familiar in the field of chemistry under the term of "chemical affinity," more to denote that field in which a more accurate knowledge was especially desirable than to combine by such a word sufficiently definite ideas. The word was there, just as the name of a future street stands on a signboard in the outskirts of a city, in a waste field; tents and barracks of the most curious kind have been erected from time to time only to be deserted again; only in most recent times solid buildings and permanent settlements have found a place on this site, and soon a new section of the city will be created there, whose importance threatens to throw the older portions of the city in the shade.

J. Willard Gibbs called the degree of intensity of chemical energy the chemical potential; analogous to the degree of intensity of electrical energy, which is called the electrical potential. So, to avoid the vagueness of the term *affinity*, we will make use of the term chemical potential, or in brief potential.

Now it follows from the definition of the degree of intensity, that two substances with like potential can not act on each other; and, conversely, that when two substances act on each other, their potential must be different.

That general law which can be regarded as expressive of the

Second Theorem holds also for the chemical potential, namely: Two potentials which individually are equal to a third are equal to each other. This proposition seems quite self-evident, and therefore equally meaningless. Yet we can draw from it conclusions that are very far reaching. It says that two bodies or groups of bodies, which are in epuilibrium with each other, can mutually replace each other at pleasure towards a third system in every reaction in which this third system (towards which equilibrium has been established) can react. Thus, for example, every soluble body can be replaced by its saturated solution, every liquid by its saturated vapor, every solid body at its fusing point by the melted body without causing any alteration in the equilibrium depending upon the former. Among other things, this shows that while the heat of solution, fusion, and evaporation change the evolution of heat during a chemical process they do not thus affect the equilibrium. The thermal theory of affinity, which is even to-day championed by Berthelot and others, is by this circumstance proved to be quite untenable.

It is natural, in the case of such a far-reaching proposition, to require proofs. This proof is found in the fact that it is impossible to create a perpetuum mobile. To have a perpetuum mobile it is not necessary to create energy from nothing, but only to transform potential energy into kinetic. If it were, for instance, possible to transform the constant heat which is present in enormous amounts in the ocean into work which then could change back into heat, we would require no more coal to propel our steamships, since all the work which we required for their propulsion would be transformed into heat by friction and could return to the ocean in unchanged amounts. Such a perpetuum mobile will be instantly possible when two substances which individually are in equilibrium with a third are not in equilibrium with each other. If we assume that a substance, A, when in contact with a large body, B (the ocean), assumes a temperature which is different from that imparted to a body, B, simultaneonsly in contact and equilibrium with the ocean, we would cause a transmission of heat between A and B which would be capable of driving a machine. This proof is equally

true for every other form of equilibrium and for every form of energy, and thus we also prove our chemical proposition.

When we have thus recognized the conditions under which energy is in equilibrium or at rest, we can directly reason that energy can not be at rest when its potentials are different. A process must then take place by means of which they become equal. This is the most common phenomenon with which we are acquainted; everything which takes place is based in the last instance upon an equalization of energies of different potentials.

Since, however, energy, as is a fact, has a never-ceasing tendency to equalize itself, the question arises why it has not done so long ago during the many thousand years which our system of worlds has existed. We continually see differences of potential existing in nature—compressed air, galvanic elements; all these contain stores of energy which are ever ready to act and must therefore be unequal. Likewise the fossil fuels and the sulphides of the metals are able in conjunction with the oxygen of the air to bring forth large amounts of energy during their interaction, and can not, therefore, be in equilibrium. Aside from the tendency for equalization, which is peculiar to energy, other forces are therefore active in nature which hinder or detain this, and an accurate understanding of these natural phenomena can only be attained when these opposing and detaining causes are known.

For mechanical and electrical energy such hindrances can be easily created. A spring may be kept wound by a weight; two electrically charged bodies, which tend to approach each other, can be kept from attaining their equilibrium by the dielectric resistance of an interposed medium. All these hindrances, however, have but this explanation, that the differences of energy present are compensated by the use of other energies, so that their equalization is prevented; at the same time, we can prove that, according to the method employed, large quantities of one form of energy of any magnitude can be compensated by equally small quantities of another form of energy, for by means of a small switch, enormous currents of electricity can be interrupted and closed at will.

In the case of chemical energy we are, however, very often

unable to prove such compensations by the application of other energies. When a piece of wood is exposed to the air, it would be in accordance with the general tendency to equalize the energy present, if combustion took place and the wood combined with the oxygen of the air. The same would apply to organized bodies. Our body consists of combustible substances; and, in accordance with the chemical affinities present, it should combine with the oxygen of the air and burn without cessation. Why is it not consumed?

If we should attempt to answer this question we should soon become entangled in inexplicable contradictions. We can not ask: "Why is our body not consumed?" since it does actually burn. It continually takes up oxygen and gives off carbon dioxide. The same answer applies to other chemical phenomena. A stick of sulphur exposed to the air seems unchanged, but it is only apparently so. In reality it is oxidized; slowly, however, and so slowly, in fact, that we would not notice it in weeks or months. If the process were, however, continued for years or decades of years, the oxidation could be measured. The rapidity of reaction is clearly proportioned to the surface. If we take finely powdered sulphur, flower or milk of sulphur, whose total surface is much greater, we can prove the formation of sulphuric acid in hours and days.

What has here been stated for a few cases is a general truth. In every case where different substances which could act upon one another are in contact without having, practically speaking, any apparent action upon each other, we can bring the requirements of the teachings of energy into unison with the actual conditions by actually ascribing to these substances an action which is, however, so slow that it lies beyond the possibilities of measurement.

We have here the means of entering upon one of the most important and mysterious problems, namely, the search after the chemical activity of organized bodies. For, as all the activity of organisms depends upon changes in their chemical energy, all knowledge in this case depends upon a correct elucidation of the character of the chemical changes. If we can understand how the chemical processes of combustion, to which all physiological sources of energy finally lead, can be so regulated that

they are able at any moment to adapt themselves to the ever-changing requirements of the organism, we have taken a step in every respect most important in the knowledge of life.

Let us take, for instance, a mixture of oxygen and hydrogen. Under ordinary circumstaces we can preserve this mixture for a long time without the formation of a measurable amount of water. If, however, we place a piece of platinum sponge into it, the formation of water immediately begins; and it is as suddenly terminated when we remove the sponge. The platinum sponge has, moreover, undergone no change and is able to exert this action for an unbounded space of time.

At first, it seems as if we had here the first proposition of our later natural science; to rudely dispute "*causa arguat effectuum*," since we have here a cause which can bring forth extended and large effects at pleasure without becoming exhausted. If we ask, however, what this proposition means by cause and effect we find it to be degrees of energy. No energy of any kind can be created without the consumption of an equal amount of energy, and no difference in the potential of energies can be called forth without the simultaneous disappearance of equivalent differences in the potential of other energies. The truth of these propositions is not cast in doubt by the experiment with the mixture of oxygen and hydrogen, since the heat of combustion remains the same both when combination is effected by an electric spark and when it is brought about at the ordinary temperature by means of platinum sponge. While, therefore, the law of cause, clothed in the form of a principle of energy, regulates the final result of the action in an unchangeable manner, the time during which this action takes place remains absolutely independent of this principle, and we have side by side with the absolute necessity of this law of cause the freedom with reference to the time during which it exerts its influence. Therefore we see that all possible phenomena which, originating from the same substances, reach the same products, arrive at these with a very different rapidity. The object to be arrived at is unchangeable; whether it is, however, to be accomplished in a second or in several thousand years is a circumstance over which we have full control.

The name "catalytic bodies" has been given to substances which cause chemical reactions without experiencing any change themselves. We will now change this definition so as to read thus: Catalytic substances are those which modify the rapidity of a definite chemical reaction without changing their own content of energy. To place a catalytic substance into the reacting bodies, and to remove it, requires theoretically no work. This proves that within the strict province of the law of energy, there still remains room for the greatest variation in the temporal extent of the phenomena.

This peculiar circumstance has its foundation in the fact that in the expression of most degrees of energy time is not mentioned, and that, therefore, the equation of energy does not determine the extent of time involved in the phenomena.

One exception is made in the case of kinetic energy which depends upon the rapidity. What has been stated above does not therefore apply to this form of energy. Upon what the action of catalytic substances depends is still a mystery, the solution of which is the more difficult, since it can only be explained by means of new principles, which are beyond the law of energy. At present, we must be satisfied with the knowledge that it is a fact, and must seek to become acquainted with the laws involved. A beginning has already been made; from a large number of various investigations it has been found that many chemical reactions, which usually take place very slowly, are hastened by the presence of free acids; or, to speak in the language of the modern theories, by the presence of free hydrogen-ions, and that this action is proportional to the concentration of the latter. The greatest variety of phenomena have been examined in this respect, partly by me, partly by my pupils, and I have as yet found no case where this statement did not apply. Free hydrogen-ions are therefore without doubt exceedingly active catalysators of a general character.

At the same time numberless *specific* catalysators exist which act only upon certain phenomena. These are the ferments, organized and unorganized. These also are unable to do more than to change the rapidity of certain reactions in one or the other respect, and all attempts to explain their action must be

based upon this, their sole property. The laws which they obey appear to be of an extremely complicated nature, especially with the more complex constituted ferments; this is probably due to the fact that they undergo a change themselves while influencing a certain chemical reaction.

I need not show in an extended manner that the wonderful action of living organisms can be traced to a regular impulse upon the chemical processes which take place among their constituents in accordance with general chemical laws, and that these again may be traced to the action of catalytic substances. If the rapidity of reaction in a muscle is hastened which may be regulated from a central organ, this muscle will accomplish a corresponding amount of work. When, however, the supply of energy is exhausted, the influence of a catalysator cannot force it to any further manifestations. The same is true for all other activities of organisms.

I cannot assume to have made clear the mystery of life in the previous pages, but I believe that I have solved a more apparent problem, namely, to show that the science which is seemingly abstract and foreign to actual life, and which has developed during the last years under the name of physical chemistry, is a science of the highest real importance. If it will be possible for this science to throw light upon that most difficult of all the problems of nature, the mystery of life, how much easier will it be to explain by means of the new principles the by far much easier problems of technical chemistry which have not been solved so far. It is quite natural and self-implied, but we must nevertheless repeat again and again that—"The more perfect the theoretical evolution of the sciences becomes, the greater will be the scope of their explanations and at the same time the greater their practical importance."

THE FUNDAMENTS OF CHEMICAL THEORY.[1]

By J. E. Trevor.

Received September 19, 1893.

The Development of Science.—The general course of development of the sciences which deal with natural phenomena follows,

[1][This paper was delivered in the form of a lecture at Cornell University. It has been substituted by Prof. Trevor for his paper before the World's Congress of Chemists, read August 26th, entitled "The Energy Theory of Chemistry; Comment upon Ostwald's paper on Chemical Energy."—Editor.]

in its beginnings, through a descriptive stage. The bare facts, the materials with which a science has to deal, are laboriously collected and, in so far as is possible, they are systematically arranged. Not until this patient collection of empirical facts has gathered together a comparatively extended mass of more or less thoroughly classified material does it become possible, with this material as a basis, to begin a study of the causal relations between the different classes of phenomena coming in question. In entering upon this second stage of development the Descriptive Science becomes a Rational Science, the discovery of *facts* gives place to the discovery of *relations*, isolated phenomena appear as parts of the coherent whole, and a completed network of its exact relations makes this science a known thing, brings its phenomena under the absolute control of the all-ruling principles of mathematics. A recognition of the connection between phenomena, and not the observation and description of individual facts, is the final aim of science.

Botany, for example, is in its development just emerging from the descriptive stage. The seeking and classifying of kinds of plants has furnished a broad basis of known fact, and men seek now to know the cause of the flow of sap in trees, to follow the transformations in the growing plant and fruit, to understand the chemistry and the mechanics of plant life. The science of physics has made a considerable progress into the rational stage, its investigations are mainly conducted under the guidance of known relations between the phenomena of heat and work, of work and electricity, of electricity and magnetism, and the like. Its world of phenomena is coming more and more under the unerring control of mathematics. But the most complete, the classical instance of this advanced stage of development is offered by solar astromony, the relations between its elements being known with such exactness that the minute details of its stupendous phenomena are foretold by computers with nothing less than an astounding accuracy. The command of man over the phenomena of the heavens is one of the most complete as well as one of the grandest achievements of the human intellect.

Our science of chemistry is in its nature like these others; its progress has hitherto been in the main that of a descriptive

science and a fearful mass of necessary chemical material has been accumulated in the course of it. And now its rapid and brilliant rationalization is attracting the attention of the scientific world.

The desultory alchemy of the middle ages had become scientific investigation when Priestley and Scheele discovered that there was such a thing as oxygen, and Lavoisier showed that matter is not to be annihilated. From this time the increase in our knowledge of descriptive chemistry has been rapid. Valuable principles of classification were furnished by the atomic hypothesis of Dalton and the molecular hypothesis of Avogadro, both appearing early in the century, and they have been employed in a systematic investigation of the properties and reactions of inorganic compounds, which has ever since been carried forward with vigor, to no slight extent under the brilliant leadership of the Swede, Berzelius. This work has been accompanied in later years by an extended study of the materials of organic chemistry, by a seeking and finding of the wonderfully simple and beautiful relations existing between the different classes of the compounds of carbon. Widespread enthusiasm and devotion in this work was kindled over a half century ago in Germany by Liebig, whose gentle memory comes down to us through the science as a charm and an inspiration. This work has enriched science with a wealth of working material, has chased back into the darkness much of the mystery of ordinary life and, in supplying the most useful of our drugs and dyes, has added greatly to the material wealth of the world.

The experimental development of descriptive chemistry, both inorganic and organic, which has made up the great bulk of chemical investigation during the present century, was necessary work and it has been rich in achievement. Yet in it and through it all there is something lacking, something which must eventually claim the supreme interest. From a descriptive science we must pass to a rational science, from the *what* of chemical phenomena we must pass to the *how* and the *why*. The observation and description of individual facts must make way for a recognition of the connection of phenomena; the primitive interest in the discovery of a new compound must vanish

to make way for a greater interest in the discovery of relations, of generalizations.

The Rationalization of Chemistry.—The latest phase of chemical science studies chemical processes as such, strives to rationalize chemistry, aims to make it a science of exact relations between classes of phenomena. And since chemical phenomena involve heat and electricity, density, temperature and the like, things which are specifically treated in the science of physics, the new trend of chemical work has come to be termed the physical chemistry. It is this to which we are now to turn our attention.

To say that the sciences of physics, of mechanics, and of astronomy are more highly developed, are more completely understood than are their sister sciences, is to say that they have been brought more completely under the control of mathematics. The more complete this rule over their phenomena becomes, the more perfect becomes their development as branches of human knowledge. In this respect, as the highest of them all, stands geometry. For twenty-two centuries now the geometry of Euclid has been the encouragement and guide of that scientific progress which is one thing with the advance of man from a worse to a better state; and it is even unto this day the highest aim of every scientific student to bring his science into such a state of perfection as that which has been attained by geometry. The deepest scientific insight shines through the words of the Pythagoreans, who called mathematics the Purifier of the Reasonable Soul, and it is the desire of each one of us to bring that branch of physical science in which he is more immediately interested into such a state that it too shall be, in a similar sense, a purifier of the reasonable soul.

To develop, now, a scheme which shall place chemistry upon the basis of an exact science we must clearly comprehend with *what* we are dealing, what the subject matter of our work really is. It may be conclusively shown that the actuality with which we have to do is *energy;* from a physical point of view the manifestations of energy constitute phenomena. From the laws of energy is derivable a coherent system of natural science, made up entirely of exact relations between the various energy phenomena coming in question. This enables us to construct a

wide-reaching and coherent theory of the changes of state, a chemical theory characterized by the stately march and all the relentless rigor of a strictly mathematical science.

And in this matter we must stand for conservatism. We must not countenance the wild hypotheses which have so often disfigured chemistry. Facts are the things with which we must deal, and we must deal with them rigorously. Hypotheses are to be used with the utmost caution and discarded whenever possible. In so doing we shall find that our science will become a purer one and that we shall be far less likely to fetter and blind ourselves by *belief* in hypotheses, which in themselves may be attractive but which are essentially unprovable and therefore unworthy of belief.

Energy.—Experience has made clear that heat, work, electricity and the like are mutually convertible; they are hence the same kind of thing and this kind of thing has received the general name Energy. Besides space and time[1] this is our most general conception, for these three quantities are the only ones which are common to all branches of physical science.

It has been more or less clearly understood ever since the time of Berkeley, ever since 1710, that the world which we perceive *is* our perceptions, is not something *inferred* from our perceptions. But the only things of which we can take direct cognizance are the manifestations of energy. We cannot see material objects directly with our eyes, what we actually do see is a picture upon the retina, produced by the radiant energy entering the eye—and in all probability the impression upon the optic nerves is more immediately due to the energy of the chemical changes taking place in the retina; the eye is an organ for radiant energy. The ear, likewise, reacts upon the mechanical energy of a vibrating gas, and the organs of touch react upon those forms of mechanical energy involving pressure or force as a factor. The only thing, then, of which we can take *direct cognizance* is energy, in one form or another. Energy, furthermore, despite its transformations, never increases nor decreases in amount; for example, it is impossible to create work out of noth-

[1] It may even be maintained that time is a derived conception, but it is difficult to see how we might dispense with it as an independent variable in treating natural phenomena.

ing and thus construct a machine which shall furnish power forever; and in any transformation of energy none is ever lost. This fact, which is based upon the widest experience of exact science, is expressed by saying that the various energy forms are mutually convertible, or, better, that the total energy of the accessible universe is constant. That which *subsists* is in its very nature a *substance*, and so, when we bear in mind that energy is the only thing of which we can directly know, we are forced to the most important conclusion that:

Energy is the only *substance* of which we *know*.

Briefly the argument is this:—

That which we perceive *is* our perceptions;

These perceptions are manifestations of energy;

Hence: That which we perceive is energy manifestations, the only thing of which we directly know is energy. Furthermore energy subsists, and is hence the only substance of which we know.

We can have no knowledge of an objective reality of matter, whether the term corresponds to anything actual we do not know and ought not to care. The notion of objective reality is inferred from the evidence of our senses; it is a derived idea, an hypothesis. The only thing of which we really know is energy, which is therefore the prime subject of human interest.

This result establishes the fundamental character of the energy idea. Any natural process is a change of one or more energy forms; the transformations of energy constitute phenomena; science, the study of phenomena, is concerned with energy alone, and its laws furnish the basis of physical theory. The rational theory of phenomena, in chemistry as well as elsewhere, is an energy theory, and its fundamental principle is the great generalization:

The Energy of the Universe is Constant.

This principle is known as the First Law of Energetics.

Energetics.—The different sciences would be wholly distinct were the several energy forms which they treat not mutually convertible. This convertibility, and this alone, unites them into a general Science of Energetics. By using space, energy and time as the units common to them all there are obtained throughout measurable relations between them. The subjects

of chemistry, electricity, heat, and work are thus brought together, and the respective transformations of the energies involved furnish the subject matter for the sciences of electro-chemistry, thermo-chemistry, electro-dynamics, thermo-dynamics, and mechanics.

It is especially to be emphasized that the different energy forms are of wholly independent character, no one of them is energy *par excellence*. There is no reason for assigning to the energy of motion an especially prominent character. Neither electricity nor heat is to be treated as kinetic energy, any more than kinetic energy is to be considered as electricity. And, furthermore, no energy form may be singled out as a "potential energy." The energy of distance is no less an energy than is that of motion into which it is transformable, and each energy is "potential" with respect to every other, in that it may be transformed into that other.

The Factors of Energy.—The possibility of developing a comprehensive and exhaustive science of Energetics depends upon the fact that the analytical expression for each energy form is resolvable into a product of two factors[1], one of which has the character of an intensity of the energy form in question, and the other that of a capacity for it. They are best known as the intensity and capacity factors. The intensity factor determines whether its energy may or may not be at rest, having, by definition, the same value for two energy quantities which do not influence each other. Such is, *e. g.*, the temperature factor of heat energy; a large mass of iron and a small one may contain very different amounts of heat but no conduction will take place from one to the other if their temperatures be the same. Examples of this resolution into factors are:

		Capacity.	Intensity.	Formula.
Mechanical Energies.	Distance energy	= distance	× force	$s \cdot f$
	Surface energy	= surface	× tension	$O \cdot \gamma$
	Volume energy	= volume	× pressure	$v \cdot p$
	Motion energy	= mass	× velocity square	$\frac{1}{2} m \cdot V^2$
Other Energies.	Electricity	= quantity	× potential	$\varepsilon \cdot \pi$
	Heat	$= \left(\frac{Q}{T}\right)$ or $\frac{dQ}{dT}$	× temperature	$\frac{Q}{T} \cdot T$
	Magnetism	= mag. quan.	× mag. potential	$e \cdot \Pi$

[1] Helmholtz, 1887; also J. W. Gibbs, 1876.

The recognition of the impossibility of an unlimited transformation of one energy form into another without intensity differences, as in obtaining work from a quantity of heat of uniform temperature, or from electricity of uniform potential, constitutes the so-called Second Law of Energetics:

Unlimited conversion of an energy, without intensity differences, is impossible.

This principle[1] is as entirely a result of experience as is the first law of energetics, formulating the observed impossibility of creating energy from nothing. They are the most fundamental laws governing natural phenomena; taken together they constitute the farthest reach of science.

Energy Equilibria.—The condition for the equilibrium of a single energy form, that its intensity shall be uniform throughout, is in its application very familiar. The heat in a bar of iron which is hot at one end will be transferred by conduction until the temperature differences shall have become equalized; a mass of gas must have uniform pressure throughout (the effect of gravitational energy supposed eliminated); electricity will not pass from one electrically charged body to another when both quantities of electricity have the same potential; two moving masses will not influence each other's motion if their velocities be the same (they must correspondingly have the same direction of motion, for the definition of a velocity includes a direction). The same rule applies to the other energy forms.

But that feature of the energy theory which is of the most especial interest at the present time is its treatment of the equilibria between several energy forms which oppose one another in the same system. Such an equilibrium is said to obtain when no transformation of one energy form into another takes place. The equilibrium eventually reached may be disturbed by a change of the intensity factor of any one of the energies involved, this causing an opposed change of the correlative energy forms. At equilibrium an infinitesimal change (virtual change) of one of the energies must be exactly balanced by the resulting virtual changes of the others.

[1] Generalized by Ostwald, 1892.

For the sake of illustration let us consider a billiard ball suspended by an elastic cord. When the system comes to rest an equilibrium is maintained between the gravitational energy, tending to pull the ball downward, and the elastic energy of the cord, tending to pull it upward. In a virtual displacement of this equilibrium, *e. g.*, pulling the ball an infinitely small distance downward, the gravitational energy expended is exactly equal to the elastic energy gained; their *algebraic* sum is zero. This is required by the first energy law. Suppose, however, the ball to be drawn downward a foot or two and then released. In its new position the two energies are not in equilibrium and, in the initial infinitesimal displacement as the ball rises, the expenditure of elastic energy exceeds the corresponding gain of gravitational energy. Only when the oscillations have ceased do the virtual changes balance each other.

The necessary and sufficient *condition of equilibrium* then, for any material system whatsoever, is

The algebraic sum of the energy changes involved in a virtual displacement of the equilibrium must equal zero.[1]

If we represent energy, capacity and intensity by E, C, and I respectively, this condition is expressed analytically by

$$\Sigma\delta E = 0 \text{ or } \Sigma C dI = 0,$$

the summation being taken over all the correlated energies of the system. It is known as the Principle of Virtual Energies and it represents the theory of all equilibria whatever, whether they be those of statics, of thermodynamics, of chemistry, or of any other branch of general Energetics.

A special case of this is the Principle of Virtual Work in statics, where the equilibria studied are between mechanical energies capable of doing work, W. When the work furnished by one in a virtual displacement is exactly counterbalanced by that of the others the mechanical system in question is in equilibrium, and the condition of equilibrium is

$$\Sigma\delta W = 0,$$

the same equation as before. Upon this relation, introduced in-

[1] Ostwald, 1892.

to mechanics by Bernouilli and Lagrange, the science of statics is based.

Force.—It may be well to insist at this point upon the distinction between force and work or energy, a distinction not always kept clear in popular speech. Reference to the table of energies already given will show that a *force* is an intensity and must move a body through a *distance* in order to do *work* upon it; the work done is the product of force and distance. The force meant acts in the direction in which the body moves; if a force f have a different direction the *acting force* is its component lying in the direction of motion, or $f \cos \theta$ when θ is the angle made by the direction of the force with the direction of motion. Opposing forces may prevent motion in which case the force is balanced and does no work. The intensity factors of the space energies, force, surface tension, and pressure, are the quotients of an energy by a distance, a surface, and a volume respectively, and they are the intensities acting through a distance, a surface, and a volume respectively. They are the same kind of quantity as is a temperature or an electrical potential. *Power* is often used as synonomous with *work*, but *force* can never be.

The term *work* is sometimes used to designate in general the energy forms which are convertible without limit, and *force* to designate their intensity factors, but in the interest of a clear terminology this usage would better be dropped.

Units.—In dealing with energy quantities it is necessary to have an established unit. The one generally accepted as a basis of reference is the *erg*, the unit of work. It is the product of unit force into unit distance, the product into one centimeter of the force giving to one gram of mass an acceleration of one centimeter per second in a second:

$$\underset{\text{Energy.}}{\text{Erg}} = \underset{\text{Force.}}{g \cdot \frac{cm}{sec} \cdot \frac{1}{sec}} \times \underset{\text{Distance.}}{\frac{cm}{1}}$$

This erg is then $g \cdot (\frac{cm}{sec})^2$, or mv^2, which is *twice* the motion energy (kinetic energy) contained in unit mass moving at unit velocity.

Nearly all the other energy units in common use are reached by the following proportionality factors:

The unit of electrical energy, of electricity, has been arbitrarily set equivalent to ten million ergs; *i. e.*

$$\text{volt-coulomb} = \frac{1}{10,000,000} \times \text{ergs.} \qquad (1)$$

The gram-centimeter, being the product into one centimeter of the gram of weight, the force giving to a gram of mass an acceleration of 980 centimeters per second in a second ($980 \frac{\text{cm}}{\text{sec}} \cdot \frac{1}{\text{sec}}$), is 980 times greater than the erg. So

$$\text{ergs} = 980 \times \text{gram-centimeters.} \qquad (2)$$

Careful determination of the proportionality factor converting work into heat units, the mechanical equivalent of heat, has given

$$\text{gram-centimeters} = 42,750 \text{ calories.} \qquad (3)$$

Outline of Chemical Theory.—The energy theory may be applied most interestingly in organizing into a concrete whole the exact relations of a rational chemical theory. A comprehensive treatment of the problems of the subject includes in the first place the immediate applications of the conservation law. Further than this, the energy equilibria with which the science of chemistry is concerned may be treated, for the purposes of classification, under three heads: First, those represented by differential equations, which are integrable because a known relation exists between the factors of the energy involved (as is the case with volume energy); second, non-integrable differential equations, furnishing a relation between the respective intensity factors; and, third, differential equations involving, in addition to the opposed energies of reacting substances, the influence of extraneous energy forms. These three grand divisions of the subject are then:

I. Volume energy integrals,
II. Simple differential equations,
III. Reaction equilibria,

and the three corresponding types of equilibrium equation are:

$$\int dW = \int C \cdot dI \qquad (1)$$

$$C' \cdot dI' = C \cdot dI \qquad (2)$$

$$\Sigma C' \cdot dI' = C \cdot dI \qquad (3)$$

where W, C, and I represent, respectively, work and the capacity

and intensity factors of energy forms. The general form of the equations remains $\Sigma\delta E = 0$; in equation (3) the summation is taken over the reacting substances on the one hand and the reaction products on the other, the energy of the one decreasing and that of the other increasing in a virtual displacement of the equilibrium of a reversible reaction. The consideration, in a general way, of the results to which these equations lead will furnish at once a complete outline of our system of Chemical Theory. It will be well to glance over the outline before taking up the work in detail, in order to gain an idea of the coherence of the theory.

I. There may be calculated[1], by means of equation (1), the amount of work gained in the expansion of a dissolved substance or of a gas from a given pressure P to a lesser one p. This will be

$$\int dW = -\int_P^p v dP$$

$$= -RT\int_P^p \frac{1^{\circ}}{P}$$

$$W = RT\log\frac{P}{p}. \qquad (1, a)$$

This expression connects the amount of work required to concentrate a solution, with the resulting change of its vapor pressure. Furthermore, the electromotive activity of the various types of electrical cells may be shown to depend upon a transformation of volume energy into electricity, and since this equation determines the change of volume energy it yields the theory of the cell[2]. The relation is a fundamental one in the Theory of Solutions and in Electrochemistry.

II. By a general application of equation (2) there may be expressed the mutual dependence of

Electricity,
Surface energy,
Heat,
Volume energy.

[1] Van't Hoff, 1887.

[2] Nernst, 1889.

We will arrange the resulting equations, for subsequent reference.

For the equilibrium between electricity and surface energy:

$$O d\gamma = -\varepsilon d\pi$$

$$\frac{d\gamma}{d\pi} = \frac{-\varepsilon}{O} \qquad (2, a)$$

This expresses the relation between surface tension and electromotive force[1].

That between surface energy and heat is

$$\frac{q}{T} \cdot dT = O \cdot d\gamma$$

$$\frac{d\gamma}{dT} = \frac{q}{T \cdot O} \qquad (2, b)$$

an expression for the temperature coefficient of surface tension[1].

For the extremely important equilibrium between electricity and heat:

$$\varepsilon d\pi = \frac{q}{T} \cdot dT$$

$$\frac{d\pi}{dT} = \frac{q}{T \cdot \varepsilon} \qquad (2, c)$$

This famous equation[1] introduces the element of temperature into the theory of electrochemistry.

Another relation of great importance[1] is obtained from the equilibrium between heat and volume energy, [(v'—v)=increase of molecular volume],

$$\frac{q}{T} \cdot dT = (v' - v) dp$$

$$\frac{dp}{dt} = \frac{q}{T(v' - v)} \qquad (2, d)$$

It comprehends the extremely extended theory of such changes of state as are involved in the processes of vaporization, sublimation, dissolving, melting and the transformation of allotropic forms, and is in consequence one of the most important relations in chemical theory.

All these special cases of equation (2) have the form

$$C' \cdot dI' = C \cdot dI$$

or

$$\frac{dI'}{dI} = \frac{C}{C'}$$

[1] First derived in this way by Ostwald, 1892.

and they express the details of what is technically known as the Theory of "Complete" Equilibria.

III. The final division of this energy system, that dominated by equation (3), is concerned with the influence of extraneous energy forms upon the purely chemical volume energy equilibria of reversible reactions. When a system of reacting substances is in equilibrium, the total virtual change Σvdp of the volume energy of the reaction products is balanced by that ΣVdP of the original substances. p and v represent throughout the partial pressures and molecular volumes of the substances in question, and when the system is left to itself our fundamental equation (3) assumes the form

$$\Sigma vdp - \Sigma VdP = o .$$

With the aid of the general "equation of condition" of dilute matter, $pv = nRt$, whence $p = nRTv^{-1}$ and $dp = -nRT\frac{dv}{v^2}$, we can eliminate the pressure factor, obtaining

$$-RT(n\Sigma d\log v - N\Sigma d\log V) = o,$$

whence, at constant temperature, replacing the molecular volume by its reciprocal the molecular concentration,

$$\Sigma d\log c^n = \Sigma d\log C^N.$$

The integral of this equation furnishes the concentration relations for a chemical equilibrium at constant temperature,

$$\Sigma\log c^n + \log k' = \Sigma\log C^N + \log k$$

i.e.

$$\frac{c_1^{n_1}\cdot c_2^{n_2}\cdot\cdot\cdot}{C_1^{N_1}\cdot C_2^{N_2}\cdot\cdot\cdot} = \frac{k}{k'} = K$$

or

$$C_1^{n_1}\cdot C_2^{n_2}\cdot\cdot\cdot = K\cdot C_1^{N_1}\cdot C_2^{N_2}\cdot\cdot\cdot$$

which states the effect of each reacting substance to be proportional to its concentration. This is the great Law of Mass Action[1], or the Reaction Isotherm, expressing the conditions of chemical equilibrium at constant temperature. Its application has brought to light a system of experimentally confirmed quantitative relations more extended than has resulted from any other law of theoretical chemistry.

If pressure be applied to a system of reacting substances work is done upon it and a deformation of its chemical equilibrium

[1] Guldberg and Waage, 1867.

results. The fundamental equation (3) represents this equilibrium between volume energy and work in the form

$$-\Delta v \cdot dp - (\Sigma v dp - \Sigma V dP) = o,$$

where—Δv is the volume decrease accompanying the reaction in question, and is a function of the specific volumes of the substances. The bracketed expression we have already found to be RTdlogK, K being at a given temperature the constant *characterizing* the equilibrium. So we have

$$\frac{d \log k}{d p} = \frac{-\Delta v}{RT} \qquad (3, b)$$

expressing the effect of pressure upon a chemical equilibrium[1].

One more case remains under this head, that concerned with the influence of temperature upon a movable equilibrium. On adding the heat quantity Q to our chemical system, the resulting balance between it and the volume energy change of the displaced chemical equilibrium is, by the governing equation (3),

$$\frac{Q}{T} \cdot dT - (\Sigma v \cdot dp - \Sigma V dP) = o$$

$$\frac{Q}{T} \cdot dT - RT\, d \log K = o$$

$$\frac{d \log K}{d T} = \frac{Q}{RT^2} \qquad (3,c)$$

This equation[2] connects the influence of temperature with the heat of reaction. Its applications to chemical phenomena have been extended and are brilliant in the extreme.

This general arrangement of the elements of chemical theory, which the energy idea leads us to adopt, takes up successively:

The Conservation of Energy,
The Theory of Solutions,
Electrochemistry,
"Complete Equilibria,"
Reaction Equilibria (including Reaction Velocities),

and includes under these heads a wealth of material really quite unanticipated by those who have not followed the results of recent research. A logical sequence has hitherto been markedly absent in what has passed for Theoretical Chemistry, and so the possibility of this coherent arrangement is a pleasing indication

[1] Planck, 1887.

[2] Van't Hoff.

that this branch of knowledge is rapidly becoming an exact science.

Free Energy.—Chemical action usually effects changes in the state of aggregation or in the density of the substances concerned and so produces work (or other energy forms, *e. g.* electricity, entirely convertible into work) as well as heat. A distinction must therefore be made between that part of the available energy capable of direct conversion into work and that part producible only as heat. The first is appropriately termed the Free Energy, the second the Bound Energy of the system.

A spontaneously occurring natural process is one taking up no energy other than heat from the surrounding medium. Every such process may be made to yield a definite maximum amount of work. For, if its available work were negative it would have to take place without absorption of energy, and on being reversed by the addition of heat would transform this heat into work. The operation might be indefinitely repeated, continually converting constant-temperature heat into work, a result in conflict with the second energy law.

Since every spontaneous process must yield work, a system incapable of yielding work (one whose free energy has minimum value) is incapable of spontaneous change, is in stable equilibrium. So this condition of equilibrium[1], deduced from the second energy law, is

The Decrease of Free Energy must be a maximum.

Processes originating spontaneously and proceeding at constant temperature can take place only in such direction as to cause a diminution of free energy, a production of energy forms convertible without limit ("work"). It is therefore the decrease of free energy, and not the heat developed, which determines the direction in which chemical affinities can become active, *and which is the measure of the work-value of the chemical forces.*

Of all possible chemical changes in a material system the one involving the greatest decrease of its free energy (the maximum available work) will occur. Neither the reaction involving maximum production of heat, nor that of maximum thermal tonality

[1] Helmholtz, 1882.

(sum of heat and work produced) will necessarily take place; there are in fact many spontaneously occurring chemical processes which absorb heat. The decrease of free energy in any given reaction is found by determining the work to be gained when the transformation is made reversible and isothermal.

The Equations of Thermodynamics.—The science of thermodynamics considers the mutual transformations of heat and work. An equilibrium between them must, in accordance with the general principle of virtual energies, be expressed by the equation

$$\frac{Q}{T} \cdot dT = dW \qquad (\alpha)$$

These energy differentials are equal. On changing by dT the temperature of the total heat quantity Q the fraction $\frac{dT}{T}$ of it may be transformed into work[1]. This work quantity dW is the maximum available, since no heat is supposed lost. The two energies being considered exactly in balance the energy displacement in question is a reversible one.

In any such change of a material system the decrease of its total energy is, according to the first energy law, the sum of the heat and work given out, so here (reckoning, as customary, positive Q as heat *added*)

Decrease of total energy. (Thermal Tonality)		Max. work given out.		Heat given out.
U	=	W	+	(−Q).

Substituting in (α) the value of Q thus given, we obtain

$$W - U = T\frac{dw}{dT} \qquad (\beta)$$

an equation of great importance in chemical thermodynamics, in that it connects the decrease of the free energy (maximum available work) of a system with its total energy change.[2]

The Energy Method.—A prominent and unfortunate phase of the history of the energy doctrine deserves especial mention in this place. In the years immediately following 1870 a singular idea worked its way into very general acceptance in the scientific world. The popular hypothesis of a molecular constitution of

[1] Clausius.

[2] Helmholtz, 1882.

matter led to the conception of heat as the kinetic energy of moving molecules, and this ingenious thought gave rise to the idea that all energy forms are manifestations of kinetic energy, kinetic energy being regarded thereupon as *energy itself*. In consequence of this, each department of exact science came to be looked upon as a branch of mechanics.

This kineticism took the scientific world by storm and, by reason of the actual impossibility of adequately treating the phenomena of electricity, heat, etc., as kinetic energies, it has exerted a seriously hemming influence upon the development of rational ideas in physics and chemistry for a good twenty years. And it is lamentably true that its evil effects have not, even yet, died wholly away from among us. Nevertheless, in this day of progress it scarcely needs to be emphasized that the chief advances made in the theory of phenomena during the last half century have been made independently of this vicious assumption of discrete molecules. Physical theory and not mechanical hypothesis has been the guiding star.

The object of science is to find and classify the relations between phenomena, and to do this in such wise that their comprehension shall be unfettered by auxiliary assumptions. It cannot be too emphatically insisted upon that a distinct line of demarcation must be maintained between that which we *know* and that which is of essentially hypothetical nature. Neglect of this elemental necessity has made chemistry a strange mixture of empirical fact and wierd hypothesis. It is a necessary principle of scientific work that only a minimum employment of hypotheses is admissible—and herein lies an especially important feature of the theory of energy. In disregarding improved assumptions, such as, for example, the mechanical hypothesis of a molecular structure of matter, it deals directly with known facts and the results which it reaches are of necessity actual relations between measurable quantities. Among them are the remarkable relations which form the framework of thermodynamics, of electrochemistry, of chemical equilibrium, of the solution theory. The mutual dependence of vapor pressure and heat of vaporization, of electromotive force and heat of reaction, of reaction velocity and temperature, of the freezing point of a so-

lution and the heat of fusion of its solvent are among the most brilliant results of exact science.

This energy method, with its fruitful principle of virtual changes, is rearing the framework of a coherent theory of chemical processes, and it is through this development of a science of exact relations that we must hope to be relieved from the thralldom of unproven, frequently unprovable and always unnecessary mechanical hypotheses. Through this appears for the first time in the history of chemistry a prospect of dealing directly with facts as such, *and only with facts*.

WORK OF THE COMMITTEES ON THE "INTERNATIONAL STANDARDS FOR THE ANALYSIS OF IRON AND STEEL."[1]

By John W. Langley, Cleveland, Ohio.

THE history of the organization and work of these committees up to the present year is briefly as follows:

In the summer of 1888 it was the fortune of the present writer to present the subject of the desirability of establishing a set of samples of steel which should be analyzed with extreme care, in order that they might become standards to which scientific and commercial analyses of iron and steel could be subsequently referred; also, that greater uniformity in the results of analyses might be brought about, since these standards would bear towards analytical methods somewhat the position which the original units of weight and length, the gram and meter, or the pound and yard, do to the mechanical arts.

The plan met with hearty co-operation, with the result that committees were appointed in Sweden, Germany, France, England, and America to receive the material and see that the necessary analyses were executed.

These committees were constituted as follows:

In Sweden, Prof. Richard Åkerman; in Germany, by the authority of the minister of public works, the execution of the analyses has been entrusted to the Konigliche Chemisch Technischen Versuchungsanstalt, in Berlin; in France, Mons. Ferd.

[1] Read before the World's Congress of Chemists, August 22, 1893.

Gautier; in England, the British Association for the Advancement of Science; in America, a joint committee from members of the University of Michigan and of the American Society of Civil Engineers.

This latter body appointed a committee of seven analysts as follows: Andrew A. Blair, Philadelphia, Pa.; Regis Chauvenet, Golden, Colorado; Thomas M. Drown, Boston, Mass.; Charles B. Dudley, Altoona, Pa.; John W. Langley, Cleveland, Ohio; Albert B. Prescott, Ann Arbor, Mich.; P. W. Shimer, Easton, Pa.

The material for analysis at first consisted of four samples of steel prepared in this country. To this was subsequently added a fifth standard selected in England by the committee for that country.

Reports of progress have been made by the English committee in the Reports of the British Association for the Advancement of Science, volumes for 1888, 1889, 1890, 1891, 1892, the last one particularly containing a full account of the work on the four original standards.

In the United States the attention of the committee was early drawn to discrepancies caused by different methods of analysis. They therefore prepared a set of supplementary samples known as the experimental standards and to be used only in reviewing methods of analysis. A full report of their work in this line will be found in the Transactions of the American Institute of Mining Engineers, volume **19,** 1890, and a brief one in volume **20.**

The Swedish committee through Professor Åkerman has made a report which will be given shortly.

The outcome of the American committee's work on the modes of determining carbon resulted in calling attention to important errors likely to occur when using double chloride of copper and ammonium as a solvent for the steel owing to the great difficulty of obtaining this salt free from pyridin and other tarry products. They recommend substituting chloride of potassium for chloride of ammonium, which is found to be a complete remedy. They also found that contrary to the usual practice this solvent must not be neutral, but must be rendered strongly acid with

from five to ten per cent. of its volume of strong hydrochloric acid.

They also call attention to the great tendency which chlorine compounds have to pass out of the combustion apparatus and to lodge in the absorption train, thus increasing the apparent weight of carbonic acid, and they give methods for arresting it.

During the past year this committee has continued its work. The communication from Professor Drown given below enumerates very fully the precautions necessary and some inevitable causes of variation in carbon determinations.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY,
BOSTON, JULY 29, 1893.

PROF. JOHN W. LANGLEY, *Chairman, Committee on International Standards for the Analysis of Iron and Steel;*

DEAR SIR: I give you herewith the results of my determinations of the carbon in the experimental steel standard. The sample examined was marked "hammered."

The amount of carbon found in six consecutive analyses was:

Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1.050	1.057	1.054	1.030	1.054	1.053

These results were all obtained by precisely the same process and method of manipulation. The agreement is satisfactory with the exception of the fourth. I know of no reason why this result should have been lower than the others. The average of the six determinations is 1.0497. If the fourth determination is omitted, which I think it reasonable to do, the average of the remaining five determinations is 1.0536 per cent.

The process used was as follows: Three grams of the steel were treated with 200 cc. of a solution of copper-potassium chloride (300 grams to the liter) and fifteen cc. of hydrochloric acid (sp. gr. 1.2). After complete solution of the iron the carbon was filtered off on an asbestos-lined platinum boat, thoroughly washed with hydrochloric acid, and then with water until the washings gave no reaction with silver nitrate. After drying, the boat was put into a porcelain tube and the carbon burned in a current of oxygen.

The oxygen used was passed over red hot copper oxide, then through caustic potash, then over calcium chloride before it entered the porcelain tube. The tube contained at its farther end several inches of copper oxide and a coil of metallic silver, which were heated to redness before the carbon was ignited.

The gases on leaving the porcelain tube were passed, first, through a small bulb tube containing an acid solution of ferrous sulphate, then over anhydrous copper sulphate on pumice, and finally over calcium

chloride before entering the potash bulb. The latter was provided with a small extension tube containing calcium chloride.

Before beginning each combustion two or three blank combustions were made to see that there was no source of error in the apparatus itself. The oxygen was swept out with air (free from moisture and carbonic acid) and the potash bulbs were closed with rubber tubing plugged with capillary glass tubes.

The silver coil, ferrous sulphate, and anhydrous copper sulphate were all used for the purpose of absorbing hydrochloric acid or chlorine. In Mr. P. W. Shimer's communication on this subject he calls attention to the fact that absorbents of hydrochloric acid are unnecessary if the acid is entirely washed out in the original filtration, an operation which would seem to be not at all difficult. I have long held the same view as Mr. Shimer, and yet I am compelled to admit that better agreeing results can be regularly and consecutively obtained if all possible precautions are taken at the time of the combustion against the entrance of chlorine or hydrochloric acid into the potash bulbs.

I am indebted to Dr. C. B. Dudley for the suggestion of the use of ferrous sulphate, and I think it a valuable addition to the process. The solution is made by adding concentrated sulphuric acid to a saturated solution of ferrous sulphate until the latter begins to crystallize out.

A series of determinations made in all respects like those given above, except that this small bulb of ferrous sulphate was not inserted, gave the following results:

Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1.073	1.080	1.051	1.051	1.037	1.040	1.049	1.069

There are three abnormally high results in this series, which do not appear in the series in which the ferrous sulphate was used.

In the course of this study I have made several hundred blank combustions to determine what errors might be introduced in the apparatus and manipulation. On some days there would be a constant gain in weight in the potash bulbs, on other days a constant loss, and again, at other times, the bulbs would not change in weight, in spite of the fact that the conditions of the experiments as to time, quantities of oxygen and air passed, and arrangement of apparatus were the same. On moist days, as every chemist of experience has observed, it is almost impossible to get a satisfactory weight of the potash bulbs, and it is also well known that differences of temperature between laboratory and weighing room must always be taken into consideration. The very least error, plus or minus, which one must count upon in the final weight of carbonic acid is, I think, 0.0003 gram. This can not be thought large when one considers the great weight of the bulbs, the large amount of oxygen and air (one or two liters) passing through them, the large surface of glass exposed, and the fluctuating conditions of humidity and temperature in the laboratory and weighing room. And yet this three-tenths of

a milligram amounts to 0.003 per cent. of the carbon when three grams of steel are used for the analysis. It seems to me that a variation plus or minus of 0.005 per cent. on carbon in steel is the very least that should be allowed in view of the many sources of error inherent in the combustion process as now generally used. And I am inclined to think that it would be very seldom that the variation on ten consecutive determinations would fall within this limit, even with chemists of experience in this line of work.

I have satisfied myself by many experiments that a small extension tube filled with very small fragments of calcium chloride attached to the potash bulbs is entirely adequate to collect any moisture that may be carried over from the potash solution, and that the latter does not allow any carbonic acid to pass through. The use of solid caustic potash in the extension tube is therefore unnecessary. Neither have I found any advantage in the addition of a drop or two of water in the bulb of the calcium chloride tube to moisten the air after it has passed the anhydrous copper sulphate.

In addition to the work above given I have made a large number of determinations of the carbon in the experimental standard under different conditions. Some of the results thus obtained it may be worth while to record. A determination made in the same series as those first given, and in precisely the same manner, except that copper-ammonium chloride was used instead of the potassium salt, gave the per cent. of carbon as 1.053. This would indicate that the ammonium salt can be safely used when free from carbon.[1] That cupric chloride acidified with hydrochloric acid can be used for the solution of the iron has already been shown by other members of the committee. I have made several experiments in this direction with the view of using this method exclusively, and thus avoid the necessity of using a crystallized double salt of copper. Cupric chloride acidified with twenty per cent. of strong hydrochloric acid dissolves iron with reasonable promptness and gives good results. The addition of forty per cent. of hydrochloric acid is apt to cause loss of carbon. But hydrochloric acid is not as good a solvent of cuprous chloride as the alkaline chlorides.

It seemed obvious that the addition of potassium or sodium chloride to the acidified copper solution would give as good results as a solution of copper-potassium chloride. Several determinations made in this way gave fairly good results. Copper oxide, containing some metallic copper, was dissolved in hydrochloric acid, chlorine gas was passed into the solution to oxidize the cuprous chloride, and the solution was then evaporated to small bulk to expel the free chlorine; it contained some free acid. The amount of copper in this solution was determined by the battery in order that the proper amount should be used in dissolving the steel. Three grams of steel were treated with an amount of this solu-

[1] This copper-ammonium chloride was obtained from Messrs. Baker and Adamson, Easton, Pa.

tion which contained twelve grams of copper, fifteen cc. of hydrochloric acid (sp. gr. 1.2) and sixty cc. of a solution of common salt containing 320 grams to the liter. The steel dissolved readily. The filtration of the carbon and the combustion were made precisely as above described with all the precaution for the interception of chlorine and hydrochloric acid. The results obtained for the carbon in three experiments were:

Per cent.	Per cent.	Per cent.	Average per cent.
1.055	1.043	1.059	1.052

A similar experiment, using potassium chloride instead of sodium chloride, gave 1.051 per cent. carbon.

I have also made a large number of experiments with silver sulphate as a solvent for the steel, but I did not obtain any satisfactory results in this way.

I take pleasure in acknowledging my great indebtedness to Mr. Wm. S. Davenport, instructor in analytical chemistry in the Massachusetts Institute of Technology, for the analytical work of this investigation, and for many valuable suggestions regarding the processes employed.

THOMAS M. DROWN.

The original four standards have now been analyzed in three countries with the following result.

The English committee give as the mean of their determinations:

ENGLISH COMMITTEE.

	Standard No. 1.	Standard No. 2.	Standard No. 3.	Standard No. 4.
Carbon	1.414	0.816	0.476	0.151
Silicon	0.263	0.191	0.141	0.008
Sulphur	0.006	0.007	0.008	0.039
Phosphorus	0.018	0.014	0.021	0.078
Manganese	0.259	0.141	0.145	0.130

The Swedish committee through Professor Åkerman give their means as:

SWEDISH COMMITTEE.

	Standard No. 1.	Standard No. 2.	Standard No. 3.	Standard No. 4.
Carbon	1.45	0.84	0.50	0.17
Silicon	0.257	0.185	0.15	0.015
Sulphur	0.008	0.004	0.006	0.048
Phosphorus	0.022	0.015	0.021	0.102
Manganese	0.282	0.145	0.17	0.13

The American members have not held a joint meeting this year and there are one or two analysts who have not completed

their work, so that the averages given below may suffer some small modification in the future.

AMERICAN COMMITTEE.

	Standard No. 1.	Standard No. 2.	Standard No. 3.	Standard No. 4.
Carbon	1.44	0.807	0.452	0.16
Silicon	0.270	0.202	0.152	0.015
Sulphur	0.004	0.004	0.004	0.038
Phosphorus	0.016	0.010	0.015	0.088
Manganese	0.254	0.124	0.140	0.098

The German committee has devoted much attention to the study of methods of analysis in connection with the international standards, but has not yet announced its results. The French committee has made no report.

STANDARDIZING THE TORSION VISCOSIMETER.

BY O. S. DOOLITTLE, CHEMIST, P. & R. R. CO.

Received October 24, 1893.

IN the article published in the June number of *Drugs, Oils, and Paints*,[1] on the Torsion Viscosimeter, the method recommended for expressing the viscosity was in the number of degrees of retardation between the first and second complete arcs. Further experience has shown that although this is the best method for any one instrument, yet when it comes to comparing different instruments it is too delicate. It has been found that two instruments cannot be made to show the same number of degrees of retardation throughout a wide range of viscosity without requiring an amount of care and exactness in the manufacture which greatly adds to their cost.

In order to overcome this difficulty each instrument is now standardized against pure cane sugar solutions, after the manner proposed by Mr. S. M. Babcock (*J. Anal. Chem.*, **1**, 151,) in a similar case, the viscosity being expressed in the number of grams of sugar contained in 100 cc. of the syrup at 60° F., which will give the retardation designated at 80° F. These readings are obtained by taking a number of solutions contain-

[1] See this JOURNAL, March, 1893.

ing known amounts of pure cane sugar, and determining the retardation of each. A curve is then mapped out on a piece of plotting paper, the number of grams of sugar in 100 cc. of the different syrups representing the abscisses, and the degrees of retardation, the ordinates. This curve enables us to interpolate the value of each degree of retardation in terms of pure cane sugar, and in this way a table of viscosities is drawn up and furnished with each instrument. This table renders the results obtained by different instruments strictly comparable.

Incidentally while experimenting with these sugar solutions I have been able to show the influence which specific gravity has on the determination of viscosity, when made by the class of instruments which allow the liquid to flow through an orifice, and express their results in the number of seconds required. The viscosity on the torsion viscosimeter of a certain oil having a specific gravity of 0.9 was found to be 86.4. I then made a sugar solution showing exactly the same viscosity, and found its specific gravity to be 1.4. These two liquids having identically the same viscosity as shown by the torsion viscosimeter but differing in specific gravity, were then run through the Saybolt viscosimeter. The oil required $35\frac{1}{4}$ seconds, while the sugar solution ran through in $30\frac{1}{4}$ seconds, thus showing that the difference in specific gravity caused an error of five seconds on this instrument by forcing the sugar solution through the orifice faster than the oil. To demonstrate still further the presence of this error, the viscosity of an oil of 0.9 sp. gr., was ascertained to be $35\frac{3}{4}$ seconds on the Saybolt instrument. I then made a sugar solution which gave exactly the same figure on this viscosimeter, showing a specific gravity of 1.48. The viscosity of these two liquids was then taken with the torsion viscosimeter, when it was found that the oil showed a viscosity of 86.8, while the sugar solution gave 91.8. In other words it was necessary to make a solution of sugar of decidedly higher actual viscosity than the oil, in order to overcome the error due to difference in specific gravity and show the same reading on the Saybolt viscosimeter.

From this it would seem clearly evident that the viscosity as determined by any instrument based on the principle of allowing

the liquid to flow from a receptacle through an orifice, has a very appreciable error due to the specific gravity of the oil.

The torsion viscosimeter is manufactured and sold by Bullock and Crenshaw, 528 Arch street, Philadelphia.

PROGRESS IN THE MANUFACTURE AND USE OF ARTIFICIAL COLORING MATTERS.[1]

By Otto N. Witt, Ph.D., Professor at the Polytechnic Institute of Berlin.

HAVING been requested to deliver an address before this congress, I know of no better subject to call your attention to than the one with which I have been familiar from the beginning, the chemistry of artificial coloring matters and their relation to dyeing and calico printing.

Unfortunately the subject is one of such vast dimensions, that I should fail to give you anything like a complete description of it, even if I could venture to trespass much longer upon your valuable time than it is my intention of doing. I had to choose a certain chapter from it, and in so doing I have preferred, mindful of the eminently practical turn of this country, to bring before you rather the practical side of the recent development of coloring matters, than the theoretical one. Thus I shall avoid among other things the use of complicated structural formulas which, though indispensable to the modern organic chemist, are apt to be looked upon with disfavor by no small number of eminent and accomplished chemists.

The question of artificial coloring matters is, I am sorry to say, one which has hitherto been left entirely in the hands of the chemists of the old world, who, I need not assure you, would be only too glad to collaborate in this matter as well as in so many others, with their colleagues in the United States. But it seems that quite peculiar conditions are required to develop this particular flower on the vigorous and imposing tree of general chemistry and we have, even in the old world, noticed the remarkable fact that the industry of artificial dye stuffs, born in France, has left that country to settle in England; and here again it has not been able to reach its full development, but has

[1] Read before the World's Congress of Chemists, August 21, 1893.

preferred, with no apparent cause, to make the German Empire its final emporium. But here at last it has grown to such imposing magnitude, that the world has now, for more than a decade, been ringing with its praise and admiration. And this praise has not been bestowed with injustice. The whole life and thought of some of our greatest scientists have been spent in considering and mastering the intricate problems connected with the chemistry of aromatic compounds, to which all synthetical dyestuffs belong and every progress of the manufacture of these interesting substances has been the result of masterly work in the domain of pure science. The method, now so generally recognized, of applying scientific principles to every practical question, however trivial it may at first seem to be, has never been more successfully adopted than in the manufacture and use of dyestuffs, where nothing may be guessed or discovered, but everything concluded and invented.

The new brilliant era in the chemistry of artificial coloring matters was inaugurated by the discovery of the law, which governs the connection of the chemical constitution with the properties of artificial dyestuffs. It would lead too far to set before you on this occasion these laws themselves and to expound the many examples of their correctness and universal applicability. But it is quite natural, that, when once these laws were established, the production of dyestuffs ceased to be the result of lucky circumstances and became the object of profound and in many cases brilliant logical argument, and thus it is that today coloring matters may be produced by thousands, all of which are absolutely and perfectly new and the properties of which may be established with perfect certainty before even the smallest sample of them has ever been prepared. So great is the number of new dye-stuffs for the production of which we have every means at our disposal, that it seems quite impossible that all of them will ever be prepared even as laboratory specimens.

Now it will be easily seen that science whilst placing a treasure of such imposing magnitude at the disposal of the manufacturer, has not only benefitted him, but that she has also vastly increased his work and responsibilities. And thus we see the

old fashioned factories, such as I remember them from the days of my youth, consisting of a few sheds and a snug little laboratory, replaced by the enormous places which now serve the same purpose and of which you may see an excellent representation in the exhibition of the German chemical industry in the World's Fair; places resembling towns or cities, consisting of hundreds of buildings of vast proportions and over-shadowed by dozens of huge chimneys; with laboratories much larger than those of the most renowned universities, and in which hundreds of chemists and assistants are constantly at work; and in the workshops themselves the few casks and stirrers which used to be the main implements of the manufacturer of dye-stuffs, have been replaced by costly machinery, too varied and complicated to attempt its description.

Now it seems natural to ask whether all this is but temporary or lasting; or, in other words, whether such complicated means for the production of artificial dye-stuffs will forever be necessary or whether, in the near future to come, all this may not be much simplified. It seems but natural to start from correct scientific principles and to conclude that we do not want such a large number of dye-stuffs as we are actually capable of producing. We know that there are a few primary colors from which all the other shades may be produced by mixture. Why not, therefore, select amongst the vast number of dye-stuffs at our disposal a few which, whilst being cheap and easy of manufacture, represent our primary shades. Let us then dye everything with these and neglect the rest, from a practical point of view. This seems sound reason, and the enormous apparatus which is at present used by the manufacturer seems to involve an unnecessary complication.

I regret to say that this way of looking at the subject proves quite erroneous if we examine it a little more closely. The simple laws of the combination of colors in the physical sense of the word are not applicable to dye stuffs used for dyeing textile materials. Coloring matters of given shades may be blended together, but it is impossible to produce, by their mixture, shades of such freshness and purity as the same shade produced by one individual chemical compound would possess.

It is easy to explain the causes of this fact, but in order to be brief we will take it as granted, and we will then see at once why such a large number of intermediate shades have to be prepared. Thus, for instance, a careful silk dyer would never think of producing a purple from a mixture of blue and red, although physically this would seem possible. He would always, to insure a good result, use any or either of the purple dye stuffs now in the market. I may say that there are at present about thirty different purples sold, and that no one of them is a mixture but a well-defined individual compound of different shade and properties.

But the color which may be produced on a textile material by a certain dye-stuff is not the only point to be considered in using this dye-stuff. Here we come to the most interesting side of the question—to the relation between the coloring matter and the process of its application.

What is the process of dyeing? This is a question which has for a long time puzzled the minds of many scientists. It is now generally admitted that it is a chemical process, a process of actual combination between the substance of the dye-stuff and the substance of the fiber. But the impossibility of establishing in the majority of cases any molecular proportions in the chemical reaction which is taking place has for a long time been the stumbling block of those who wished to examine this reaction more closely. It is only quite recently that the true nature of the process has been recognized. Dyeing is certainly a chemical process, but one of those in which simple molecular proportions can no longer be established. These processes have of late been more closely investigated, and we now comprise them under the heading of solutions. If I dissolve sugar in water, a chemical reaction, a combination of the two ingredients takes place, and the solution formed is a chemical compound, whatever be the proportion of its constituents. And the same rule applies in a great many other cases.

The difficulty in grasping the true scientific sense of the word "solution" lies in the fact that we have from our childhood been accustomed to consider a solution as something liquid. This is by no means a necessity, and there are quite as many

solid solutions as liquid ones. To give you an example I will take blue glass. This is a solution of sodium-cobaltic silicate of an intensely blue color in colorless normal crown or flint glass. Both the constituents of this solution are solids, and so is the solution itself; still the two compounds in combining together do so according to exactly the same principles as sugar and water in producing a liquid solution.

Without going into details I may state that every dyed fiber may be looked upon as a solid solution of exactly the same character as blue glass. Its mode of formation is different, but the result is none the less the same.

Taking this as established, we may at once draw an interesting conclusion. If for dissolving sugar we take spirit instead of water we find at once that sugar is much less soluble in this medium. Now there is quite as much difference between silk and cotton as there is between spirit and water, and thus we understand why the different textile fibers can not be dyed with equal facility. The chemical substance of the fiber being the solvent for the dye-stuff, it is but natural that its solvent power should not be equal in all cases. Thus it is that we have to use different dye-stuffs for the various textile fibers, and, as the number of the latter is rather on the increase than the reverse, we shall have to meet in the future a demand for an increased variety of the dye-stuffs produced.

The discovery of the true relation between the dye-stuff and the fiber has coincided with some of the most important forward steps in the industry of artificial coloring matters, and in some respects has been instrumental in facilitating such progress.

The majority of the older dye-stuffs have been remarkable for their solubility in, or, as the chemists of the old school would express it, for their affinity for silk and wool rather than for cotton and the other cellulose fibers. In applying them to cotton certain artifices had to be used, known as mordanting, processes into the nature of which we need not enter, but which made the dyeing of cotton both difficult and expensive. But when we remember that the relation of the two solvents, spirit and water, to sugar is not a universal one; that there are a great many substances which dissolve easily in spirit and spar-

ingly or not at all in water, we see at once that there is no reason why the same should not apply to dye-stuffs and why there should not be dye-stuffs which, contrary to those hitherto produced, dissolve more easily in cotton than in silk or wool. If such dye-stuffs could be produced, their production would of necessity represent an immense progress in the dyeing of all vegetable fibers, of which, as you are aware, about ten times as large a quantity is consumed all over the world as of silk and wool taken together.

Well, this progress was realized about eight years ago, when the first synthetical dye-stuff more soluble in cotton than in animal fibers was put on the market under the name of Congo. This compound dyes cotton a brilliant scarlet without the use of a mordant. Ever since its discovery many chemists have been at work inventing new dye-stuffs which, whilst being endowed with the same important property, would supply the other shades, and at present we have several hundreds of them, dyeing every shade of the spectrum and placing the cotton dyer on the same convenient footing with the silk and wool dyer. I need hardly add that the relations between the constitution of these dye-stuffs and their interesting new properties have been fully cleared up, and that the production of all the varied shades of this new class of coloring matters is the result of truly scientific and logical work, and not in the least that of lucky chance.

There are many more things of general interest which I might bring before you, but I prefer to limit myself to the discussion of but one more important subject.

This important subject is the question of the fastness of artificial dye-stuffs, of their power of resistance to the chemical action of the various conditions to which a dyed textile fabric must of necessity be exposed.

I may state at once that there are few things in chemistry about which so many and such unfounded popular prejudices are afloat as this question of the fastness of artificial coloring matters.

It is true that the first synthetical dye-stuffs placed on the market, magenta and its derivatives, were of a rather fugitive

character. But there is no logical connection between this unfortunate fact and the artificial production of the substances to which it applies. If by some chance we should discover that magenta occurs as a natural constituent of some gorgeously colored flower or fruit, it would be equally fugitive; whilst alizarine and indigo, when prepared by artificial means, showed themselves quite as fast and permanent as when extracted from the plants in which they occur. In fact, I need not point out to an assembly of chemists that there is no barrier which divides natural coloring matters from artificial ones, that permanent and fugitive substances occur in both groups, and that it is the task of the colorist to make a proper selection amongst them. But in order to be able to make such a selection he requires a very large stock to choose from, and thus modern organic chemistry in placing at our disposal an overwhelming number of new coloring matters has conferred upon us a boon which can not be over estimated,—the possibility of choosing our dyeing materials not only according to the beauty of their shade, but also according to their more hidden, inherent value. We possess now artificial dye-stuffs of such a degree of permanence that neither indigo nor any other of the most renowned old natural dye-stuffs can even approach them. Most interesting and severe tests have been made which prove this beyond any doubt, and I can only invite you to look at the specimens illustrating these tests and exhibited in the collective exhibition of the German chemical industry in the Manufactures Building.

The researches on the permanence of artificial dye-stuffs, which have yielded these important results, have also been instrumental in exposing another silly and illogical popular prejudice. This prejudice consists in the belief that all bright and brilliant dyes are necessarily of a fugitive nature and that on the other hand permanent coloring matters are invariably of sombre and subdued shades. Recent researches have shown that no such relation exists between the brilliancy of dye-stuffs and their fastness. Whilst both these properties are functions of the constitution of dye-stuffs, there seems to be no inherent connection between them. And thus I may confidently recom-

mend to the ladies among this audience to continue the use of bright and pleasing colors without any fear of their being fugitive merely on account of their brilliancy. Rhodamine, the new pink, surpassing in its beauty even the delicate leaves of the rose, is not only a brilliant, but also a fast color, and it does by no means stand alone amongst modern artificial dye-stuffs in combining these two most valuable properties.

And now, ladies and gentlemen, I will not trespass upon your time any longer. My sketch of the recent progress in the chemistry of artificial dye-stuffs has of necessity been short and incomplete; but if I have succeeded in convincing you that this domain of organic chemistry has not been lying dormant of late and that all its progress has been the result of laborious and difficult, but in its final results, brilliant and successful scientific work, I shall consider myself amply rewarded.

HOW CHEMISTRY IS BEST TAUGHT.[1]

By Charles F. Mabery.

THE subject, "How Chemistry Is Best Taught," which has been proposed to us for discussion, has a serious interest for all persons who are engaged in teaching chemistry, and it is of especial importance to those of us who have in charge the preparation of young men for professional employment. In view of the prominence of scientific subjects and methods in the present systems of education, it is encumbent upon the adherents of these methods to demonstrate by their results that they are not in error in assuming that science should have an equivalent place with other departments of knowledge. In the higher institutions this question has received a definite answer; in the secondary schools evidently much has yet to be accomplished in the direction of general education as well as in the preparation for higher study.

That the importance of a knowledge of elementary chemistry is apparent to all who are capable of appreciating its usefulness is evident in the recent extension of instruction in the secondary

[1] Read before the World's Congress of Chemists, August 26, 1893.

schools. In the larger portion of our high schools, however, physical science still occupies a subordinate place, or it is taught merely from text books with little if any laboratory training. Probably the chief hindrance to any radical change is a lack of appreciation on the part of the public. If parents could be brought to see that their sons and daughters would receive a better education if physical science properly taught formed an essential feature of the high school course the change would not be long delayed. That the training of many teachers is scarcely more comprehensive than they are called upon to impart is of less importance, since at present those who are educated in the higher institutions have better opportunities and those who are deficient can improve their knowledge in special courses for teachers. Doubtless the many popular movements of the present day will exert a beneficial influence in extending an acquaintance with the application of scientific principles. Such unique and instructive object lessons as that which has been designed under the direction of Professor Ellen H. Richards for the Rumford kitchen in the Columbian Exposition can not fail to attract public attention. It requires no particular training in observation to recognize the difference in food value between a plate of Boston baked beans and an equivalent weight of potatoes; but when an appetite whetted to the sharpest edge in an endeavor to see all the exhibits in the Liberal Arts Building in one visit, and the unavailing efforts to extract a crumb of comfort from the places so improperly named, is brought in contact with the wholesome dishes prepared in the Rumford kitchen and their satisfying influence, the numbers representing the food values will be in a favorable connection to awaken a desire for further information. The same principle is applied in a different manner in the exhibits from the agricultural stations which explain the composition of dairy products, of animal foods, and the methods of chemical investigations. Such exhibits have a particular interest for persons engaged in agricultural pursuits, since they are a part of the well-directed efforts of the stations in disseminating knowledge. Probably in no department of education has there been a more substantial growth during the last twenty years than on the part

of intelligent farmers in applying the practical information coming to them from the results of investigations carried on at the experiment stations. These illustrations may seem somewhat removed from the main question before us, but I am convinced that the efficiency of higher instruction in chemistry will be greatly improved when students coming to us from the secondary schools shall have had the advantage of practical training in elementary physical science, and I believe this will be the sooner accomplished through a recognition of its benefits in the affairs of every day life.

I think we shall all agree that the best argument to be urged in favor of a prominent place for chemistry in any grade of instruction is the value of experimental methods for the development of mental power. This feature should naturally appear with especial prominence in courses leading to the degree of bachelor of arts; and if the schools of science are to be maintained on a higher plane than the trade schools or shops, the courses of study must be conducted with reference to the attainment of mental discipline and scholarship. In the courses in chemistry I am unable to see why this should interfere with the acquisition of practical knowledge.

The guiding star to successful teaching in chemistry is the personality and enthusiasm of the instructor. With the great increase in attendance in many institutions the earlier relations between student and instructor, which were frequently mingled with deep personal feeling somewhat akin to veneration on the part of the student, are well nigh impossible. Nevertheless, an enthusiastic teacher with tact and good judgment has little difficulty in maintaining a profound interest even in large classes. In successful teaching we all know how much depends upon the attitude of the instructor toward his students. Courteous relations with a clear understanding that teacher and students are mutually interested in the acquisition of knowledge readily secures the confidence and esteem of a body of students and the instruction need seldom be interrupted by questions of conduct. A faithful teacher does not limit his attention to the brighter minds; students slow in comprehension but earnest in application secure a store of information which will be used

later to the best advantage. It was a wise teacher who said: "I am faithful in my duty to dull students; in my old age I may need favors of the men of wealth."

In assimilating their methods from European laboratories, the chemists of the United States, untrammeled by traditions and unrestrained by the influence of any particular school, have been in favorable conditions to appreciate the labors of the great masters of other countries. Unfortunately it may be, in the wonderful development of our natural resources, the temptation to enjoy material benefits may have retarded the growth of original investigation; yet looking toward the future the erection of so many large laboratories can not fail under judicious control to contribute to the advancement of knowledge. A marked individuality in our methods is apparent even in a casual inspection of American laboratories. Variation in details is a natural consequence of differences in the temperament of different peoples; and teachers educated abroad have perceived the necessity of adapting the methods in which they were trained to the peculiar conditions.

It is with some hesitation that I approach that aspect of our subject which relates to the details of methods, since the best success in teaching is so dependent on the personality of the instructor that it would seem presumptuous to suggest a rigid scheme for all. There are certain principles at the foundation of successful teaching, however, which may properly be presented for consideration. I have already alluded to an unsatisfactory condition in the methods employed in the secondary schools. In some of the high schools, as we all know, there are teachers who are thoroughly imbued with the spirit of scientific study,—would there were more of them. Yet competent teachers are often limited in their efforts by a heavy burden of other work, or by a need of the necessary appliances. There can be no question that the high school courses would be benefited if every pupil received systematic training in elementary physical science, and I believe it is consistent with due attention to other subjects, and that it can be accomplished without any unreasonable pecuniary burden. As an expeditious and effective method for teaching chemistry in the high

school, I would have the teacher meet the class before the lecture table, and demonstrate, experiment, and explain, simply as a convenient mode of teaching classes as one pupil should be taught. The experiments should be repeated by the student in the laboratory under the immediate oversight of the teacher, with the note book close at hand. A text book is necessary to give information which the teacher has not time to include; but no text book can supply the need of personal teaching. Occasionally teachers with limited knowledge are led to adopt methods of questionable utility by the arrangement of certain text books. Some years since a teacher in one of the high schools in the east, in which little attention was given to laboratory work for students, remarked that his pupils must have a thorough knowledge of valence and structure symbols. The topical arrangement of the subject may be left to the discretion of the teacher and the quantity to the length of time available; but it should never be forgotten that the educational value of such instruction depends upon the development of skill in manipulation, of correct habits of observation and in recording notes, and of the true spirit of scientific thought. Whatever of practical information may be included will enhance the utility of the instruction.

In the higher institutions the first course is general and descriptive chemistry, of which every person who expects to engage in any scientific pursuit should have a thorough knowledge; and, as has been suggested, this subject should have a suitable place in college courses. Concerning details of the most efficient methods in teaching general chemistry, no doubt an extended course of experimental lectures closely connected with laboratory practice affords the best training. The ground can be fairly covered in seventy or eighty lectures with four to six hours a week of laboratory work so arranged that the lectures of each week shall include the experiments for the laboratory. Weekly recitations on the subjects of the lectures and laboratory work enable the instructor to control the progress of his students. When students first enter the laboratory it is essential that they be impressed with the necessity of accuracy in the details of experimental work. This important lesson

may easily be taught by means of experiments capable of affording quantitative results. By some instructors such experiments are occasionally introduced throughout the course with the same object in view. There should be sufficient instruction in the laboratory for careful oversight of the experimental work and the note book of each student. Moreover, I am convinced that it is unwise in any grade of undergraduate study in chemistry to allow students in laboratories without constant supervision. When left to themselves they are apt to loiter, to contract careless habits, and to waste material.

Then a laboratory is held responsible for accidents, even though they occur through inexcusable carelessness of students. Every instructor in charge of a laboratory will no doubt recall heedless moments on the part of students. Some years ago, just as I entered my qualitative laboratory one day when the assistant was out of the room, I observed a student inflate his lungs twice from a bottle containing a freshly charged solution of hydrogen sulphide. He immediately fell into the arms of a companion, and it was some time before he recovered. Probably another inhalation would have proved fatal. This fellow was a sophomore, having taken one year in general and descriptive chemistry. He was fairly bright and had been using this reagent during several months. But some question arose as to the odor of the unadulterated gas, and forgetting the precepts of his freshman year, he attempted by a direct experiment to ascertain the truth.

What has been said concerning the personality of the instructor applies perhaps in a more restricted sense to the student. While methodical habits are to be strenuously insisted upon, the methods may be sufficiently flexible to allow the student to reach his conclusions in his own particular way; the particular form of the lecture and laboratory notes, for example, can be left to the preference of the student provided they are well written and complete.

For other students than those who desire special training in chemistry or in allied subjects an extended course in general and descriptive chemistry provides ample knowledge of this subject. Analytical chemistry is next in the sequence of studies

and for evident reasons qualitative analysis is first undertaken. On account of its great disciplinary value, I regard this subject as one of the most important in the whole course of chemical training. It enables the instructor constantly to test the faithfulness and proficiency of the student, and beside the mental discipline, the student acquires a comprehensive knowledge of methods of separation and identification, which is the foundation of quantitative analysis. Elementary theoretical chemistry or chemical philosophy may be conveniently and profitably taught at the same time with qualitative analysis, especially since a familiarity with stoichiometry and chemical reactions is essential in a good understanding of quantitative methods.

Thus far in teaching chemistry probably the methods are not materially different in the college and the technical school. Indeed, in the more advanced subjects, the principal difference is in the attention which should be given to the acquisition of practical knowledge in the technical courses. The methods of quantitative analysis are well adapted for the development of skill and dexterity in accurate manipulation, and to the chemist they are indispensable. As a preparation for professional employment the training in methods should be sufficiently comprehensive and thorough to enable the student to appreciate the conditions of any analytical problem; and further, I deem it of much importance that students have practice under guidance in all typical standard methods. It is not sufficient that men shall have been carefully trained in methods which impart skill and accuracy; it seems more desirable, for example, that men who enter the iron and steel industry shall be thoroughly familiar with the standard methods of iron analysis than to rely upon skill and general knowledge to acquire the special features in actual practice. The first lessons to be learned in the quantitative laboratory are accuracy and confidence; the importance of a close economy of time and effort must be appreciated, and an intelligent student will soon perceive the numerous ways for conducting analytical operations rapidly without haste. When a chemist assumes the duties of a position, every motion has a pecuniary value, and results are demanded in the smallest limit of time. This requirement is sometimes urged in favor of undergraduate training in rapid

methods. While some practice in this direction would without doubt be serviceable, in three terms at most which can be devoted to quantitative analysis the time is fully occupied in gaining a familiarity with methods, and in passing from one analysis to another the conditions are not favorable for commercial rapidity. As in actual practice, it is only possible to attain to the highest degree of accuracy and celerity when the attention of the analyst is limited to a moderate number of determinations which are continually repeated. Experience shows that well-trained students are not slow in acquiring commercial dexterity even to reporting the percentage of carbon within five minutes after a ladle of steel is poured into the mould, or a complete analysis of blast furnace slag within thirty minutes. If attempts were made to give such practice to students, there would still be much to learn in the different conditions in the laboratory of the manufacturing plant.

A branch of our subject, which has doubtless occasioned some of us much perplexity in our endeavors to give it a suitable place in an undergraduate course, is organic chemistry. Our difficulty is partly due to the feeling on the part of certain students when they have gained a good acquaintance with quantitative analysis, with the consciousness that they can secure some pecuniary return from their attainments, that they have learned all of chemistry that can be of service to them. Usually such students may be made sensible of their error, although, unfortunately, the importance of a broader view is not always appreciated until a knowledge of this subject is needed in professional occupation. That organic chemistry is a difficult subject students are not long in perceiving. It is not sufficient in a course of lectures that the principles and methods are understood; they must be learned. The importance of a broad and thorough training in theoretical and descriptive organic chemistry as a part of a chemical education is beyond question. As a part of the preparation for technological and applied chemistry, organic chemistry can most conveniently be placed in the third year; yet without some introduction I have found this subject too difficult for third year students. The plan which I have adopted with satisfactory

results includes recitations in the first term of the third year from an elementary text book with the following lectures extending throughout the second term and the first term of the fourth year. So far as possible, laboratory practice should accompany the lectures, although from the pressure of other work the greater portion of the experimental work may be pushed forward into the fourth year. In connection with the lectures students should be required to extend their knowledge by reading, and recitations are necessary to ensure faithful application. With this arrangement the principal laboratory work of the fourth year includes organic chemistry and chemical technology, assaying, gas analysis, and such other special subjects as may seem expedient can be provided for here. A course of lectures in metallurgy is of advantage to students in chemistry, and they may be attended during this year. Some additional instruction in theoretical chemistry can be given with profit.

For the utilization of chemical skill the field of manufacturing or applied chemistry is full of promise, although in this country it has largely to be developed. Suitable preparation for industrial occupation demands thorough training in the directions already suggested, and beside a good knowledge of technical processes with the aid of laboratory work so far as it is feasible to experiment with these processes on a laboratory scale. Concerning the best methods for teaching this subject, no doubt courses of lectures supplemented by reading are to be preferred, especially if part of the lectures can be given by persons engaged in professional pursuits. Several recent compilations in a convenient form for the use of students are a valuable aid.

The range in laboratory work is of necessity somewhat limited. It must consist principally in the preparation of chemical products from crude materials, in the study of mordants and dyes, and in testing the efficiency of certain features of industrial processes on a laboratory scale. The preparation of theses or written accounts of various processes should also form a prominent feature of a course in technological chemistry. Institutions fortunately situated near manufacturing establishments afford valuable opportunities to students who are enabled

to study industrial methods in actual operation. Such instruction supplemented by laboratory practice constitutes the best possible education in applied chemistry that an institution can provide.

Any discussion of the details of a chemical education must be incomplete without some reference to related subjects, either such as are closely allied to chemistry, or those which are essential in the proper mental development of every well educated person. Evidently this portion of our subject may be considered from more than one point of view. In a course of four years in the school of science there should be thorough training in mathematics so far as Calculus, and it can be no disadvantage to make a certain portion of this subject required or optional. Every chemist who aspires to a position beyond that of an analyst will be called upon to plan and oversee the construction of appliances and buildings; in fact, ingenuity and mechanical skill may occasionally be as serviceable as chemical knowledge. There are, therefore, good reasons for the acquirement by every student of a good understanding of mechanical drawing and of elementary mechanics, and this may have led to the foundation in several institutions of a course in chemical engineering. No doubt this course is in demand by persons who desire proficiency in the engineering features, but students who expect to engage in applied chemistry can hardly afford to omit any portion of the undergraduate training in chemistry. Nothing need be said as to the importance to all chemists of thorough discipline in descriptive physics with laboratory practice. A familiarity with the principles of heat and electricity with the manipulation of electrical currents are among the more important requisites. The rapid growth of electro-metallurgy indicates large possibilities for the application of electrical energy in this form, and it can evidently be best undertaken by the chemist who possesses a good knowledge of electricity. The literary training in scientific courses is usually limited to the English branches and the modern languages. Without a certain acquaintance with the latter the chemist would be seriously restricted in the sources of his information; and, moreover, to scientific students it would seem that the French

and German languages should be taught as much at least for mental discipline and culture as for their practical usefulness. Of the importance of thorough discipline in the English language and literature, history, logic and political economy, it is not necessary to speak. Determinative mineralogy may be provided for in the second or third year. Courses in agricultural or pharmaceutical chemistry, or in other special fields, should differ in the details of the third and fourth years from the course outlined above.

In college and university courses theoretical chemistry and chemical literature receives more attention, and in general less attention is given to practical applications. I do not accept the idea sometimes expressed that original investigation should not be attempted outside of the university. We are all too well aware of the difficulties in the way of carrying on special study in connection with the responsibility of undergraduate courses; and yet I am sure we appreciate the influence of such work in the atmosphere of the laboratory, as well as upon the instructor himself. Then there are always in the laboratory bright students who are able to undertake with profit the study of special problems. As a part of the preparation for teaching I look upon a certain acquaintance with the methods of original research as an essential attainment. I do not intend to assert that without it there can be no good teachers; but it certainly strengthens the equipment of a teacher who aspires to a high position.

Earlier in this paper I endeavored to give an outline of what seems to be the principal objects to be kept in view in teaching chemistry as an educational subject. Students continue in chemistry with the intention of securing professional employment either in teaching or in applied chemistry. How often are we met with the question as to what is the prospect of employment after graduation; whether the inducements are more promising in teaching or in practical fields. Concerning teaching as a profession the reply is easy. A person with an aptitude for teaching and with broad training has little difficulty in securing a position commensurate with his attainments, especially at present with the wonderful extension of our educational

institutions. But the number of positions is limited and there are few vacancies. If they were abundant not all persons even with the best possible preparation would succeed in teaching chemistry. In applied chemistry the conditions are not the same. With our enormous stores of natural products yet undeveloped, vigorous enterprise in business operations, and great industrial wealth, there can not fail to be rapid developments in the fields of manufacturing chemistry. Within the ten years just elapsed we have witnessed great changes; manufacturers who ten years ago conducted their operations almost without the aid of chemical skill now employ several chemists. Eight years ago I visited a large plant for the manufacture of sulphuric acid which contained neither a Glover nor a Gay Lussac tower. Further improvements which are necessary for the production at home of the chemical products that are now imported in large quantities require broad qualifications with extended experience; if our graduates are not sufficiently well trained, chemists will be secured elsewhere.

If there are portions of the educational field in chemistry which appeal to us with greater force than others, perhaps the elementary teaching in the secondary schools and the advanced study in preparation for teaching or for positions requiring independent skill and originality in methods are worthy of attention. The recent growth of knowledge within special fields has introduced new features into methods of instruction. In addition to courses which are adapted for all students, those who intend to undertake investigations in any particular direction should have training under the guidance of a specialist in that field. There are many economic problems of the utmost importance awaiting solution, which require not only the application of all accumulated knowledge, but the discovery of new methods. The maintenance of a healthful water supply and the economic disposal of sewage are serious problems for the present generation, and the engineer must be aided by the best skill of the chemist and of the bacteriologist.

Every laborer is directly interested in the promotion of investigations on an economic and healthful food supply. To the great army of workmen who are struggling to support families

on incomes of three or four hundred dollars a year it is a matter of serious importance to secure the best nutrition at the smallest cost. Yet it is rarely, if ever, that a judicious selection of food materials receives attention. It is usually a question of individual taste so far as the means at hand will permit, with a complete ignorance of any principles of economy or health. In these directions and others of no less importance there are great opportunities in the domain of sanitary chemistry to render inestimable benefits to humanity.

What has been said of sanitary chemistry applies with equal force to medical chemistry, to agricultural chemistry, and to other special fields. But I feel sure that the details of the methods of instruction, as well as a consideration of methods based on other recent discoveries, such as the use of models in teaching structural chemistry, can best form a part of the general discussion by teachers who are especially occupied in those particular fields. Perhaps, also, the great border land between chemistry and physics, or chemical physics, should receive attention from those whose investigations are extending our conceptions of the fundamental principles of chemistry.

If I have presented this subject more especially from the standpoint of the preparation for professional occupation, it is because this seems to be the principal demand for instruction in chemistry beyond the elementary branches. But if the value of training in chemistry as a factor in liberal education has not been set forth with due prominence, it should receive just consideration in the discussion which follows. I have not attempted in this paper to include methods or conditions outside of our own institutions. Yet we can not fail to derive great benefit in extending our knowledge of the methods in other institutions through the eminent professors with whom it is our good fortune to meet.

PATENTS OF INTEREST TO CHEMISTS.

EDITED BY ALBERT H. WELLES.

Ore Separators, Etc.—**503,454**, August 15, Dilworth, R., ore separator. **503,687**, August 22, Seymour, C. E., ore concentrator. **503,034**, August 8, Brierly, C. B., ore amalgamator. **503,504**, August 15, Straker, S., pulverizing apparatus. **503,765**, August 22, Johnson, J. S., amalgamator.

502,663, August 1, Eldridge, G. M., washer and concentrator. 503,023, August 8, Willsie, C. F., separator. 504,240, August 29, Patterson, G. H., dry mineral separator. 504,200-201, August 29, Conklin, G., magnetic concentrator. 503,839, August 22, Fauvel, C. J., method for refractory ores; the falling stream of finely divided ore is oxidized and desulphurized by the action of pure hot air and steam passing in the opposite direction, the incandescent particles of ore then being suddenly quenched in cold water. 502,431, August 1, Eames, H. H., desulphurizing metallic ores; the ores are mixed with carbon and lime, heated in a closed vessel, and subjected to the action of the electric current.

Gold and Silver.—502,902, August 8, Evans, G. R., amalgamation of precious metals; a composition of soda, lime, and an oleaginous substance is added to the pulp and mercury in the pans. 504,109, August 29, Macay, J. F. N., extraction of silver from ores; treat ores with cupric chloride, eighty-six parts, and sodium chloride, 424 parts, to one part native silver or silver sulphide. 503,358, August 15, St. Cyr, T. Z. H., composition of matter for coating with silver, containing silver cyanide, potassium cyanide, and water, a solution containing from $\frac{3}{1338}$ to $\frac{5}{1338}$ total weight of silver.

Iron and Steel.—504,282-308, August 29, Shaw, S., a cupola furnace for melting iron. 502,492, August 1, Höfer, H., refining iron; the liquid metal is conducted through a zigzag channel and reducing gases are passed through the channel in the opposite direction. 502,482, August 1, Dauber, A., process of making iron; ore and flux without carbon are charged into the furnace, a gas containing oxygen is introduced at the zone of preparation, carbon, super-heated steam, and hot air are introduced at the zone of carburization, carbon, super-heated steam, air, and a heated combustible gas at the zone of melting, and into the crucible containing molten metal, a mixture of gas, super-heated steam, and air. 503,423, August 15, Kidwell, J. W., glazed iron; due to titanium. 503,816, August 22, Walrand, C., and Legenisel, E.. process of manufacturing steel.

Zinc.—502,822, August 8, Lewis, G. T., impure zinc oxide is treated with water and a caustic alkali, sulphur salts of zinc are dissolved, and zinc oxide is precipitated.

Tin.—504,238, August 29, Owen, D., apparatus for purifying molten tin.

Aluminum.—503,070, August 8, Broadwell, E. C., coating with the metal. 503,900, August 22, Case, W. E., manufacture of aluminum fluosulphate. 503,901, Aug. 22, Case, W. E., aluminum compound. 503,929, Aug. 22, Hall, J. B., electrolytic method for aluminum; the current is passed through a fused bath of aluminum, sodium, and lithium chlorides.

Acids.—503,847, August 22, Hacker, F. B., and Johnson, A. C., sulphuric acid apparatus. 503,286, August 15, Luhmann, E., carbonic acid manufacture. 503,557, August 15, Solvay, E., apparatus for distillation of hydrochloric acid. 504,264, August 29, Bergmann, F. J., wood-

vinegar manufacture. **502,424**, August 1, Precht, H., meta or pyrophosphoric acid combinations are obtained from phosphates of the alkali metals by melting the insoluble salts with a salt of the alkali metals and rapidly cooling to prevent crystallization.

Water.—**503,140**, August 15, Hoppes, J. J., apparatus for purifying water. **502,408-409**, August 1, Thomas, J. E., and Grow, E. P., aerating distilled water.

Brewing and Distilling.—**504,074**, August 29, Bradley, E., and Dickerson, E. N., increasing yield of alcohol from alcoholic distilled liquors. **504,145**, August 29, Zwietusch, O., beer manufacture. **503,168**, August 15, Schneider, G. H., brewing beer.

Tanning and Dyeing.—**503,235**, August 15, Grognet, F., a composition of clay, talc, and barium oxide for preparing hides. **503,987**, August 29, Ruemelin, G., tanning; cleaning hide with Glauber's salt, then with a solution of ammonia and grease or oil. **504,012-013-014**, August 29, Zahn, W., tawing hides or skins; chrome-alum, zinc sulphate, sodium chloride, potassium sulphide, manganese sulphate are used, and the reduction of chromium acid compounds by arsenite salts is covered by **504,013**. **503,148**, August 15, Lauch, R., substantive brown dye. **502,912**, August 8, Poirrier, A. F., and Rosenstiehl, D. A., black azo dye. **502,765**, August 8, Schmidt, R. E., blue alizarin dye. **502,603**, August 1, Bohn, R., green-blue alizarin dye. **503,305**, August 15, Bender, F., orange dye; derived from acridin. **502,368**, August 1, Lauch, R., and Krekeler, C., black azo dye. **502,369**, August 1, same patentees, reddish blue azo dye. **503,237**, August 15, Heftler, M., and Benard, G., apparatus for extracting dyes, tanning liquors, etc., from stock containing them.

Organic Compounds.—**502,504**, August 1, Thoms, H., para-phenetol carbamide. **503,748**, August 22, Lederer, L., amido-crotonyl-anilid, $C_{10}H_{10}(NH_2)NO$. **503,295**, August 15, Schmidt, R. E., hexaoxyanthraquinone and process for making it. **503,066**, August 8, Thoms, H., salicylate of para tolyldimethyl-pyrazolon. **503,743**, August 22, Geromont, F., lactyl-paraphenetidid. **503,401-402**, August 15, Borgmeyer, C. L., pyroxylin solvent and its compounds; the former is an ethyl alcoholic solution of oil of caraway chaff; the second substitutes oil of clove-buds for the oil of caraway. **502,546**, August 1, Borgmeyer, C. L., pyroxylin solution; effected by dissolving pyroxylin in oil of lemon grass. **502,547**, August 1, same party, pyroxylin dissolved in amyl alcohol solution of oil of cedar leaf. **502,921**, August 8, Borgmeyer, C. L., pyroxylin solvent; oil of cassia, artificial or synthetical.

Paints and Varnishes.—**504,064**, August 29, Field, W. D., varnish. **504,211**, August 29, Gallinowsky, ship's paint; hydro-magnesite, quicksilver chloride, and metallic oxide are given as the ingredients. **503,424**, August 15, Kidwell, J. W., pigment or paint; contains oxide of titanium and asphalt.

Plasters, etc.—**503,592**, August 22, Flynn, J., composition for plaster;

"sand or marble dust, gypsum, slaked lime, talc, mineral pulp, potassium carbonate and glue absorbed in quick-lime." **503,425,** August 15, Kidwell, J. W., non-corrodible plastic composition for building blocks, titanic materials, and asphalt. **503,336,** August 15, Turnbull, G. A., composition of matter for roofing; contains "gypsum, plaster of Paris, powdered salt and flowers of sulphur."

Miscellaneous.—**503,583-584-585-586-587,** August 22, Dupont, F. G., and P. S., smokeless explosives. **502,416-417.** August 1, Groat, E., apparatus for reducing and softening bituminous rock. **503,028,** August 8, Archbold, G., extracting hydrocarbons from bituminous rock; subjecting rock to sulphurous acid. **503,556-558,** August 15, Solvay, E., treatment of pulverulent materials. **503,451,** August 15, Case, W. E., apparatus for electrolysis of fused salts. **502,360,** August 1, Holland, E. K., regenerative salt furnace. **502,642,** August 1, Tatham, E., illuminating gas; contains pure oxygen and a heavy carbonaceous gas. **503,612,** August 22, Meitzler, G. R., silver cleaning and polishing composition; "whiting, powdered soap bark, oil of sassafras and carmine" are claimed. **504,105,** August 29, Corleis, E., and Reinsch, H., carbon rods for electric arc lamps; carbon impregnated with tungstic acid or a salt of the acid. **504,199,** August 29, Cheever, J. D., preserving fibrous materials; a solution of catechu, potassium bichromate, and creosote are used. **502,867,** August 8, Schüler, L., fire-proofing composition; ammonium phosphate and ammonium sulphate are given. **502,964,** August 8, Habedank, C. F., composition for lithographic transfers; "water, partly neutralized nitric acid, and tannic acid." **503,801,** August 22, Mills, J. E., composition for tempering; "oak ashes, water, tallow, slaked lime, salt, ground horn, and potassium cyanide."

NEW BOOKS.

REACTIONS. A SELECTION OF ORGANIC CHEMICAL PREPARATIONS IMPORTANT TO PHARMACY IN REGARD TO THEIR BEHAVIOR TO COMMONLY USED REAGENTS. BY F. A. FLÜCKIGER, PH.D., M.D. Translated, revised, and enlarged by J. B. Nagelvoort, analytical chemist to the Pharm. Chem. Laboratory of Parke, Davis & Co. Authorized English edition. Detroit, Mich., U. S. A. George A. Davis. 1893. pp. x + 154.

This work aims to give the physical properties and principal reactions of the more important organic chemical preparations used in medicine. The book opens with a numbered list of the reagents most commonly used and their preparation, and then follow 109 pharmaceutical products alphabetically arranged, with from one to ten reactions under each. Rather more than one-half the compounds treated of are alkaloids, among which

those of opium and the cinchona bark occupy a prominent place; nearly one-third are synthetic products introduced into pharmacy within the last few years. The compounds are well selected and the various reactions are fully and minutely described. As far as the scope of the book goes, the work is excellently and accurately done, and this is especially the case with the opium and cinchona alkaloids. Very few errors mar the book, and these few are evidently typographical, as "$C_5H_2(CH_3)$" for $C_5H_2(CH_3)_3N_4O_2$, as the formula of theobromin (p. 145); "mercurous nitrate, (Millon's reagent)," p. 25,—Millon's reagent is mercur*ic* nitrate, and the reaction given for brucin is very different from that originally described by Flückiger with mercur*ous* nitrate.

The book, however, would have had a more practical value if its scope had not been confined so closely to the narrow limits of identity reactions. Differential reactions are indicated only by reference, and in the case of almost two-thirds the compounds not a single differential reaction is pointed out. A synoptical table of the principal reactions studied would have greatly enhanced the value of the book. Further, it is stated in the preface that the "reactions * * * are not to be relied upon where impurities of any kind are likewise to be considered." The chemist does not, however, always meet with pure substances, and while in a few instances methods of purification and of identification in the presence of impurities are given, these might with value have been multiplied. The reagents are generally designated merely by a number ("Reagents 6, 12, 13, 14, 16, and 24 give precipitates," p. 72, etc.), referring to the table at the opening of the book; this saves space, but its advisability from a chemical standpoint is questionable.

The translator's additions are valuable and the translation is generally well made, though in a few instances obscure (cocain, last sentence), or too literal ("amorph powder," p. 39; "the slowly colored in the cold * * * fluids," p. 51). The spelling laid down in the rules of the A. A. A. S. is used, and the book is neatly printed on fine paper, with wide margins for notes.

J. L. H.

A GUIDE TO STEREOCHEMISTRY. ARNOLD EILOART. 96 pp. Price, $1.00. New York. Alexander Wilson. 1893.

In this book by Dr. Eiloart the endeavor is made to summarize the mass of speculation which has been published of late concerning the stereochemistry of carbon and nitrogen compounds. Although the volume is designed to serve as a text book the author's treatment is largely confined to recent speculative work, and it gives undue prominence to insignificant and weak points. As a text book planned to give a clear idea of results more generally accepted, the classical little *Stéréochimie* of van't Hoff (new edition, 1892) is likely to be of more service. Full half of Dr. Eiloart's book is devoted to an alphabetized list of citations, and to this is appended an illustrated description of wooden models (tetrahedra) designed to represent the structural formulas of organic compounds. J. E. T.

Note on the Determination of Phosphorus.—Mr. Edward K. Landis writes to the editor as follows: "I have been using for nearly a year a ground glass funnel for phosphorus after Dudley's method and find that the paper sticks tightly to the glass, permitting the upper edge to be thoroughly washed, and thus avoiding a source of error mentioned by Dudley in 'Discrepancy in Chemical Analysis.' This may prove useful to others."

ERRATUM.

In the July number, page 385, eighteenth line from the top, "(*and methyl orange*)" should read "(*and not methyl orange.*)"